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CYBERNETICS, COMPUTERS AND AUTOMATION TECHNOLOGY

ALL-UNION CONFERENCE ON COMPUTER TECHNOLOGY

Present, Future of Computer Technology

Kiev PRAVDA UKRAINY in Russian 7 Sep 77 p 3

[Text] The all-union conference "Future and Problems of Computer Technology," dedicated to the 60th anniversary of the October revolution, opened yesterday, the 6th of September, in the hall of sessions of the Kiev city soviet. A correspondent of PRAVDA UKRAINY interviewed Academician G. I. Marchuk, vice president of the USSR Academy of Sciences, recipient of the Lenin Prize, and Hero of Socialist Labor.

"This conference," said Guriy Ivanovich, "is conducted by the State Committee on Science and Technology of the USSR Council of Ministers, the USSR Academy of Sciences, the Academy of Sciences of the Ukrainian SSR, and the Institute of Cybernetics of the Ukrainian Academy of Sciences. Its principal task is to summarize the state of development of this important scientific and technological field and to form a long-term view of the further intensive development of computer equipment for the requirements of the national economy. At the center of attention will be such problems as the creation of computer equipment for broad applications and its efficient use in various realms of human endeavor. Problems in the automation of planning and design work and the automation of scientific research are especially important. These problems constitute the ground work at the present time for the effective use of computer equipment in our country."

The serious nature of the questions examined at the conference determined in advance those who would attend: executives of the State Committee for Science and Technology of the USSR Council of Ministers, managers from a number of ministries, leading scientists from institutes of the USSR Academy of Sciences, from academies of sciences of the union republics, from branch scientific research organizations and VUZ's, directors and other managers of industrial enterprises, designers, and others have all arrived in Kiev.

In opening the conference, B. E. Paton, president of the Academy of Sciences of the Ukrainian SSR, spoke of the great attention devoted by the party and government to the development of computer technology.

On the program of the conference are reports by managers of the USSR ministries of the radio industry, of instrument building, automation equipment and control systems, of the electronics industry, of communications, of the communications equipment industry, and others.

Scientists will report on the further development of the Unified Computer System, the prospects for the development of a system of small computers, and the creation of computers based on new principles of computer processing.

The last of the 3 days of the all-union conference will be devoted to visits to the Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR.

Taking part in the work of the conference are the president of the Council of Ministers of the Ukrainian SSR, I. P. Kochevykh; the vice president of the USSR Academy of Sciences, G. I. Marchuk; V. P. Vashchenko, an executive of the Central Committee of the Communist Party of the Soviet Union; heads of departments of the Central Committee of the Ukrainian Communist Party V. D. Kryuchkov and V. M. Shramenko; the first deputy chairman of Gosplan of the Ukrainian SSR, V. A. Masol; executives of the Central Committee of the Ukrainian Communist Party; executives of the State Committee on Science and Technology of the USSR Council of Ministers; and executives of the presidium of the Academy of Sciences of the Ukrainian SSR.

Forum for Creators of Computer Technology

Kiev PRAVDA UKRAINY in Russian 9 Sep 77 p 3

[Text] New models of computer equipment, complexes for the automation of industrial processes, equipment for the control of engineering calculations and planning--all were shown today to guests at the Institute of Cybernetics of the Ukrainian Academy of Sciences. Eminent scientists and managers and specialists from national ministries and departments visited the computer center for common use formed with the support of the institute. The center has already provided assistance to hundreds of enterprises and organizations. The director of this scientific institution, Academician V. M. Glushkov, discussed its work in detail.

The guests of the Kiev cybernetics specialists were participants in the 3-day all-union conference "Future and Problems of the Development of Computer Technology," which has completed its work. At the conference were heard more than 20 reports and presentations which provided a glimpse into the future of "thinking machines" and shed light on the

primary tasks of providing for the growing national demand for this equipment anticipated in the resolutions of the 25th congress of the Communist Party of the Soviet Union.

This was the most widely representative meeting in recent years of specialists in the field according to the vice president of the USSR Academy of Sciences and Hero of Socialist Labor G. I. Marchuk, who attended. Along with scientists engaged in basic theoretical research, there was active participation in the discussion of current problems by workers and specialists introducing the achievements of cybernetics and computer technology directly into the national economy. The conference will further the establishment of closer contact between institutions and organizations working on this important problem and the closer coordination of the efforts of all groups.

"New technologies--microelectronics, large-scale integrated circuits, optical devices, and integrated optics--make it possible to reexamine computer structure, making it more flexible and bringing it closer to the perception of a direct link between man and computer," remarked G. I. Marchuk. There is no doubt that the coming years will mark the appearance of new computer equipment which will greatly expand the range of applications.

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ELECTRONICS AND ELECTRICAL ENGINEERING

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SYNTHESIS OF THE OPTIMAL STRUCTURE OF A RADIO DIRECTION FINDER WHICH SIMULTANEOUSLY DETECTS A SIGNAL AND MEASURES THE ANGLE OF INCIDENCE OF THE WAVE

Kiev IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY. RADIOELEKTRONIKA in Russian
Vol 20 No 8, 1977 pp 65-72

[Article by G.M. Kurilenko]

[Text] Using the methods of statistical decision theory, relationships are given which define the optimal structure of a radio direction finder, which simultaneously detects a determinate signal and measures the angle of incidence of the wave with independent observations at discrete points in time. The resulting structure differs from the structure of devices which carry out the detection and measurement operations separately. Derived as special cases are the well-known algorithms for the detection and bearing reading of a signal.

Synthesized in [1, 2, 3] are optimum structures for radio direction finders with the presupposition of the necessary existence of a useful signal at the output of the antenna system, something which leads to a structure in which the operations of signal detection and measurement of the angle of incidence of the wave are accomplished separately. This paper is based on the hypothesis that a useful signal does not necessarily exist at the output of the antenna system. Making statistical decisions under similar conditions was treated in [4, 5] from a general point of view. The purpose of this work is to derive expressions which determine the optimum structure of a radio direction finder which simultaneously detects the signal and measures the angle of incidence of the wave, given the following observation conditions.

The antenna system of the radio direction finder incorporates two mutually perpendicular loop antennas and an omnidirectional antenna. Present at the output of each antenna, along with the useful signal, is fluctuating interference in the form of Gaussian noise, $\xi(t)$, with a zero mean value. It

is assumed that the useful signals take the form of harmonic oscillations of known amplitudes, frequency ω_c, and phase ψ_0^*.

The signals from the loop antennas, $u_{c1}(t)$ and $u_{c2}(t)$, contain the information parameter Θ:

$$u_{c1}(t)=U_0\cos(\omega_c t+\Psi_0)\sin\Theta,\quad u_{c2}(t)=U_0\cos(\omega_c t+\Psi_0)\cos\Theta,$$
$$0\leqslant t\leqslant T.$$

The angle of incidence of the wave Θ defines the direction to the radiation source.

The signal $u_{c3}(t)$ from the omnidirectional antenna is written in the form:

$$u_{c3}(t)=U_0\cos(\omega_c t+\Psi_0),\quad 0\leqslant t\leqslant T,$$

where [0, T] is the observation interval.

We shall designate the additive mixture of signal and interference at the output of the i-th antenna as $X_i(t)$. Let one of the two mutually exclusive hypotheses have a probability of being true of p_r, r = 0,1, $p_0 + p_1 = 1$:

$$H_0: X_i(t)=\xi_i(t),\quad H_1: X_i(t)=u_{ci}(t,\Theta,U_0,\Psi_0)+\xi_i(t),$$
$$0\leqslant t\leqslant T,\quad i=\overline{1,3}.$$

We shall describe the statistical properties of the processes being observed, $X_1(t)$, $X_2(t)$ and $X_3(t)$ for each hypothesis H, by the conditional finite-dimensional probability density, $w_r(\vec{x}_i^n|\Theta, U_0, \Psi_0)$, $\vec{x}_i^n\in\varkappa_n$, where $\vec{x}_i^n$, i = $\overline{1,3}$ are vectors with components of $x_{ij} = x_i(t)$, j = $\overline{1,n}$; t_j are arbitrary fixed points in time in the interval [0, T]; $\varkappa_n$ is the sample space.

The problem considered below consists in the fact that on the basis of the values of the observed realizations $x_1(t)$, $x_2(t)$ and $x_3(t)$, t $\in$ [0, T] of the processes $X_1(t)$, $X_2(t)$ and $X_3(t)$, one of the hypotheses H_r, r = 0, 1, is to be adopted (for example, H_1), and the estimate $\hat{\Theta}$ of the value of the parameter Θ is to be calculated, $0 \leqq \Theta \leqq 2\Pi$. We shall assume in this case that Θ is a random quantity with a known probability density $w(\Theta)$. The solution of this problem leads to a system for the simultaneous detection of a signal and the evaluation of its parameter with respect to the resulting sample values at discrete points in time for the observed processes $X_1(t)$, $X_2(t)$, and $X_3(t)$.

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* Such a model is not adequate for many real signals, but permits an illustration of the specific feature of the combined synthesis of the detection and measurement operations. Generalizations of the resulting expressions for more complex models of useful signals do not run into any fundamental difficulties, althought the corresponding relationships can prove to be cumbersome and inconvenient for analysis.

We shall use as the optimality criterion for such a system the minimum of the mean risk, R, for the case of the subsequent loss function, Π, which takes into account the consequences of making the decisions:

$$\Pi(\hat{\Theta}, \hat{v}, \Theta, v) = (\Pi_{\substack{\hat{\Theta}, \hat{v} \\ \Theta, v}}(\hat{\Theta}, \Theta)) = \begin{bmatrix} \Pi_{00}\Pi_{01} \\ \\ \Pi_{10}\Pi_{11}\,(\hat{\Theta} - \Theta)^2 \end{bmatrix}. \tag{1}$$

where v is a quantity which takes on a value of 0 or 1 depending on the absence or presence of a received signal; $v \in \{0,1\}$, $\hat{v}$ is the estimate of the parameter v.

With such a choice of the loss function, the problem of simultaneous detection and measurement reduces, practially speaking, to the problem of evaluating the two parameters Θ and v. We write the simultaneous estimate of these parameters in the form $\gamma' = (\hat{\Theta}, \hat{v})$, $0 \leqslant \hat{\Theta} \leqslant 2\pi$, $\hat{v} \in \{0, 1\}$. . The estimates $\hat{\Theta}$ and $\hat{v}$ are functions of the vector quantities $\hat{\Theta} = \hat{\Theta}(\vec{X}_1^n, \vec{X}_2^n, \vec{X}_3^n)$, $\hat{v} = \hat{v}(\vec{X}_1^n, \vec{X}_2^n, \vec{X}_3^n)$.

For fixed values of the parameters Θ, v, U_0 and Ψ_0, the conditional risk can be written in the form:

$$r(\Theta, v, U_0, \Psi_0) =$$

$$= \int_{x_n} \Pi(\hat{\Theta}, \hat{v}, U_0, v)\, w(\vec{x}_1^n, \vec{x}_2^n, \vec{x}_3^n | \Theta, v, U_0, \Psi_0)\, d\vec{x}_1^n d\vec{x}_2^n d\vec{x}_3^n,$$

where $(\vec{x}_1^n, \vec{x}_2^n, \vec{x}_3^n | \Theta, v, U_0, \Psi_0)$ is the simultaneous conditional probability density of the vectors $\vec{X}_1^n, \vec{X}_2^n, \vec{X}_3^n$.

The expression for the mean risk will have the form:

$$R = \sum_{i=0}^{1} P\{v=i\} \int_0^{2\pi} r(\Theta, v=i, U_0, \Psi_0)\, w(\Theta | v=i)\, d\Theta =$$

$$= \int_{x_n} w(\vec{x}_1^n, \vec{x}_2^n, \vec{x}_3^n)\, J(\hat{\Theta}, \hat{v}; \vec{x}_1^n, \vec{x}_2^n, \vec{x}_3^n)\, d\vec{x}_1^n d\vec{x}_2^n d\vec{x}_3^n,$$

where $J(\hat{\Theta}, \hat{v}; \vec{x}_1^n, \vec{x}_2^n, \vec{x}_3^n) = \sum_{i=0}^{1} \int_0^{2\pi} \Pi(\hat{\Theta}, \hat{v}, \Theta, v=i)\, w(\Theta, v=i | \vec{x}_1^n, \vec{x}_2^n, \vec{x}_3^n$

$U_0, \Psi_0)\, d\Theta$ is the a posteriori risk; $w(\Theta, v=i | \vec{x}_1^n, \vec{x}_2^n, \vec{x}_3^n, U_0, \Psi_0) = P\{v=$

$= i | \vec{x}_1^n, \vec{x}_2^n, \vec{x}_3^n\}\, w(\Theta | \vec{x}_1^n, \vec{x}_2^n, \vec{x}_3^n; v=i)$ is a function which defines the simultaneous probability density of the parameters Θ and v. $P\{v=i\} = p_i$, $i = 0,1$

are the a priori probabilities of the absence or presence of a signal; $w(\Theta|v=i)$ is the a priori probability density of the parameter Θ.

The expressions for the a posteriori risk in the evaluation of $\hat{v} = 0$, corresponding to the assumption of the hypothesis that a signal is absent at the input to the radio direction finder, and the evaluation $\hat{v} = 1$, corresponding to the assumption of the hypothesis that a signal is present, can be written in the following form for the selected loss matrix (1):

$$J_{\substack{\wedge \\ v=0}} = p_1 \Pi_{01} \int_0^{2\pi} w(\vec{x}_1^n, \vec{x}_2^n, \vec{x}_3^n | \Theta, 1, U_0, \Psi_0)\, w(\Theta|1)\, d\Theta, \tag{2}$$

$$J_{\substack{\wedge \\ v=1}} = p_0 \Pi_{10} w(\vec{x}_1^n, \vec{x}_2^n, \vec{x}_3^n | v=0) + p_1 \Pi_{11} D_\Theta(\vec{x}_1^n, \vec{x}_2^n, \vec{x}_3^n), \tag{3}$$

где where

$$D_\Theta(\vec{x}_1^n, \vec{x}_2^n, \vec{x}_3^n) = \int_0^{2\pi} \overset{\wedge}{(\Theta - \Theta)}^2 w(\vec{x}_1^n, \vec{x}_2^n, \vec{x}_3^n | \Theta, 1, U_0, \Psi_0)\, w(\Theta|1)\, d\Theta$$

is the a posteriori dispersion of the parameter Θ.

If the values of the processes being observed at the fixed points in time are statistically independent, and the noise vectors at the outputs of the various antennas are likewise independent, then:

$$w(\vec{x}_1^n, \vec{x}_2^n, \vec{x}_3^n | \Theta, v, U_0, \Psi_0) = [(8\pi^3 \sigma_{\xi_1}^2 \sigma_{\xi_2}^2 \sigma_{\xi_3}^2)^{3n}]^{-1/2} \times$$

$$\times \exp\left\{ -\sum_{i=1}^{n} \left[\frac{[x_{i1} - u_{c1}(t_i, \Theta, U_0, \Psi_0)]^2}{2\sigma_{\xi_1}^2} + \frac{[x_{i2} - u_{c2}(t_i, \Theta, U_0, \Psi_0)]^2}{2\sigma_{\xi_2}^2} + \right.\right.$$

$$\left.\left. + \frac{[x_{i3} - u_{c3}(t_i, U_0, \Psi_0)]^2}{2\sigma_{\xi_3}^2} \right] \right\}.$$

Expression (2), for an a posteriori risk for the estimation $\hat{v} = 0$, and a uniform a priori probability density of the parameter Θ, has the form:

$$J_{\substack{\wedge \\ v=0}} = p_1 \Pi_{01} [(8\pi^3 \sigma_1^2 \sigma_2^2 \sigma_3^2)^{3n}]^{-1/2} \exp\left\{ -\sum_{i=1}^{n} \left(\frac{x_{i1}^2}{2\sigma_1^2} + \frac{x_{i2}^2}{2\sigma_2^2} + \frac{x_{i3}^2}{2\sigma_3^2} \right) \right\} \times$$

$$\times e^{-b/\sigma_3^2} e^{-a_3/\sigma_3^2} \frac{1}{2\pi} \int_0^{2\pi} \exp\left(\frac{a_1}{\sigma_1^2} \sin\Theta + \frac{a_2}{\sigma_2^2} \cos\Theta + \frac{b}{\sigma_1^2} \sin^2\Theta + \frac{b}{\sigma_2^2} \cos^2\Theta \right) d\Theta, \tag{4}$$

where:

$$\left.\begin{aligned} a_1 &= \sum_{i=1}^{n} x_{i1} U_0 \cos(\omega_c t_i + \Psi_0); \quad \sigma_{\xi_1}^2 = \sigma_1^2 \\ a_2 &= \sum_{i=1}^{n} x_{i2} U_0 \cos(\omega_c t_i + \Psi_0); \quad \sigma_{\xi_2}^2 = \sigma_2^2 \\ a_3 &= -\sum_{i=1}^{n} x_{i3} U_0 \cos(\omega_c t_i + \Psi_0); \quad \sigma_{\xi_2}^2 = \sigma_3^2 \\ b &= \sum_{i=1}^{n} \frac{U_0^2 \cos^2(\omega_c t_i + \Psi_0)}{2} \end{aligned}\right\} \tag{5}$$

Expression (3) for the a posteriori risk for the case of the evaluation $\hat{v} = 1$ under the same conditions will assume the form:

$$\begin{aligned} J_{\substack{\wedge \\ v=1}} &= p_0 \Pi_{10} [(8\pi^3 \sigma_1^2 \sigma_2^2 \sigma_3^2)^{3n}]^{-1/2} \exp\left\{ -\sum_{i=1}^{n} \left(\frac{x_{i1}^2}{2\sigma_1^2} + \frac{x_{i2}^2}{2\sigma_2^2} + \frac{x_{i3}^2}{2\sigma_3^2} \right) \right\} + \\ &+ p_1 \Pi_{11} [(8\pi^3 \sigma_1^2 \sigma_2^2 \sigma_3^2)^{3n}]^{-1/2} \exp\left\{ -\sum_{i=1}^{n} \left(\frac{x_{i1}^2}{2\sigma_1^2} + \frac{x_{i2}^2}{2\sigma_2^2} + \frac{x_{i3}^2}{2\sigma_3^2} \right) e^{-b/\sigma_3^2} e^{-a_3/\sigma_3^2} \times \right. \\ &\times \frac{1}{2\pi} \int_0^{2\pi} (\hat{\Theta} - \Theta)^2 \exp\left(\frac{a_1}{\sigma_1^2} \sin\Theta + \frac{a_2}{\sigma_2^2} \cos\Theta + \frac{b}{\sigma_1^2} \sin^2\Theta + \frac{b}{\sigma_2^2} \cos^2\Theta \right) d\Theta. \end{aligned} \tag{6}$$

The integral in expression in (4), for the case of $\sigma_1 = \sigma_2 = \sigma_3 = \sigma$ (5), can be written in the form:

$$\frac{1}{2\pi} \int_0^{2\pi} \exp\left\{ \frac{1}{\sigma^2} [(a_1 \sin\Theta + a_2 \cos\Theta) + b] \right\} d\Theta = \frac{1}{2\pi} \exp\left\{ \frac{1}{\sigma^2} [c \sin(\varphi + \Theta) + b] \right\} d\Theta,$$

where $c = \sqrt{a_1^2 + a_2^2}$, $\varphi = \operatorname{arc\,tg} \frac{a_2}{a_1}$. . By means of the substitution u = $= \frac{\pi}{2} - \phi - \Theta$, this integral reduces to a zero order Bessel function of the imaginary argument [6]:

$$G\frac{1}{2\pi}\int_{-3/2\pi-\varphi}^{\pi/2-\varphi} e^{-i\left(i\,\frac{1}{\sigma^2}\,c\cos u\right)}\,du = GI_0\left(\frac{c}{\sigma^2}\right), \tag{7}$$

where $G = e^{-b/\sigma^2} = \text{const}$.

Taking (7) into account, expressions (4) and (6) will assume the form:

$$J_{\substack{\wedge\\ v=0}} = p_1\Pi_{01}\left[(8\pi^3\sigma^6)^{3n}\right]^{-1/2}\exp\left\{-\sum_{i=1}^{n}\left(\frac{x_{i1}^2+x_{i2}^2+x_{i3}^2}{2\sigma^2}\right)\right\}\; G^2e^{-a_3/\sigma^2}I_0\left(\frac{c}{\sigma^2}\right), \tag{8}$$

$$J_{\substack{\wedge\\ v=1}} = p_0\Pi_{10}\left[(8\pi^3\sigma^6)^{3n}\right]^{-1/2}\exp\left\{\sum_{i=1}^{n}\left(\frac{x_{i1}^2+x_{i2}^2+x_{i3}^2}{2\sigma^2}\right)\right\} +$$

$$+ p_1\Pi_{11}\left[(8\pi^3\sigma^6)^{3n}\right]^{-1/2}\exp\left\{-\sum_{i=1}^{n}\left(\frac{x_{i1}^2+x_{i2}^2+x_{i3}^2}{2\sigma^2}\right)\right\}\times$$

$$\times\; G^2e^{-a_3/\sigma^2}\frac{1}{2\pi}\int_0^{2\pi}(\hat{\Theta}-\Theta)^2\,e^{\frac{1}{\sigma^2}\,c\cos\left(\frac{\pi}{2}-\varphi-\Theta\right)}\,d\Theta. \tag{9}$$

To minimize the mean risk, such a value of $\hat{\Theta}^*$ for the evaluation of $\hat{\Theta}$ is to be chosen from the interval $[0, 2\pi]$ so as to assure a minimum value of the a posteriori risk $J_{\substack{\wedge\\ v=1}}$ for the case of hypothesis H_1.

It follows from (9), that the minimum value of the a posteriori risk $J_{\substack{\wedge\\ v=1}}$ is achieved with a minimum value of the second term, which depends on the value of the estimate $\hat{\Theta}$. To find the value $\hat{\Theta}^*$ of the estimate $\hat{\Theta}$, we differentiate expression (9) with respect to $\hat{\Theta}$, and following simplification, we obtain the following expression for the value $\hat{\Theta}^*$ which minimizes the a posteriori risk when $\hat{v} = 1$:

$$\hat{\Theta}^* = \frac{\frac{1}{2\pi}\int_0^{2\pi}\Theta e^{\frac{1}{\sigma^2}\,c\cos\left(\frac{\pi}{2}-\varphi-\Theta\right)}\,d\Theta}{I_0\left(\frac{c}{\sigma^2}\right)}.$$

Consequently:

$$\min_{\Theta\in[0,2\pi]} J_{\substack{\wedge\\ v=1}}(\hat{\Theta},\ 1,\ \vec{X}_1^n,\ \vec{X}_2^n,\ \vec{X}_3^n) = J_{\substack{\wedge\\ v=1}}(\hat{\Theta}^*,\ 1,\ \vec{X}_1^n,\ \vec{X}_2^n,\ \vec{X}_3^n).$$

The decision making rule for the simultaneous detection of the signal and the measurement of the angle of incidence of the wave can now be written in the form:

$$\gamma=\begin{bmatrix}\hat{\Theta}\,(\vec{X}_1^n,\ \vec{X}_2^n,\ \vec{X}_3^n)\\ \hat{v}(\vec{X}_1^n,\ \vec{X}_2^n,\ \vec{X}_3^n)\end{bmatrix}=\begin{cases}\gamma_1=\begin{pmatrix}\hat{\Theta}^*\\1\end{pmatrix}, & \text{if}\ \text{если}\ J_{\substack{\wedge\\v=0}}>J_{\substack{\wedge\\v=1}},\\ \gamma_0=\begin{pmatrix}0\\0\end{pmatrix}, & \text{if}\ \text{если}\ J_{\substack{\wedge\\v=0}}<J_{\substack{\wedge\\v=1}}.\end{cases} \tag{10}$$

We shall substitute the values of the a posteriori risks (8) and (9) in the right side inequality of (10), and after simplifying and taking the logarithm of both parts,, one can finally write:

$$-\frac{a_3}{\sigma^2}+\ln I_0\frac{\sqrt{a_1^2+a_2^2}}{\sigma^2}\underset{\gamma_0}{\overset{\gamma_1}{\gtrless}}\ln\left[\frac{p_0\Pi_{10}}{p_1\Pi_{01}G^2}+\right.$$

$$\left.+\frac{\Pi_{11}e^{-a_3/\sigma^2}\dfrac{1}{2\pi}\displaystyle\int_0^{2\pi}(\hat{\Theta}^*-\Theta)^2\,e^{\frac{1}{\sigma^2}\left(\sqrt{a_1^2+a_2^2}\right)\cos\left(\frac{\pi}{2}-\varphi-\Theta\right)}d\Theta}{\Pi_{01}}\right]. \tag{11}$$

In the general case, the structure of the device (Figure 1a) will incorporate, besides the blocks for signal detection 1, and measurement of the parameter Θ 2, and threshold unit 3, a block for fine setting of the threshold 4, the structure of which is determined by the second term on the right side of inequality (11). The block for the fine setting of the threshold makes it possible to evaluate the precision in the measurement of the parameter Θ.

We shall consider two special cases of the structure found here.

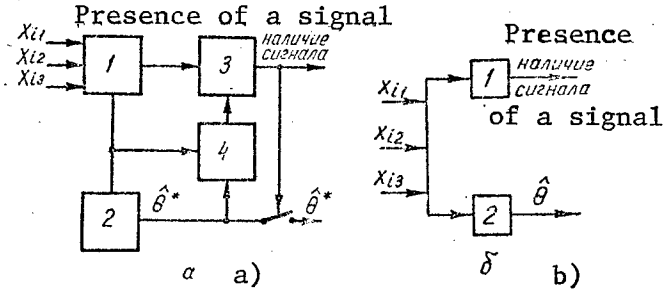

Figure 1. Structural schematic of a radio direction finder.
a. Simultaneous, and,
b. separate detection and measurement.

We shall assume that where correct decisions are made concerning the presence or absence of a signal, the elements of the loss matrix are $\Pi_{oo} = 0$ and $\Pi_{11} = 0$. In this case, decision making rule (11) will assume the form:

$$-\frac{a_3}{\sigma^2} + \ln I_0\left(\frac{\sqrt{a_1^2+a_2^2}}{\sigma^2}\right) \underset{\gamma_0}{\overset{\gamma_1}{\gtrless}} c^*,$$

where

$$c^* = \ln p_0 + \ln \Pi_{10} - \ln p_1 - \ln \Pi_{01} - \frac{2b}{\sigma^2}.$$

The structure of the device in this case will consist of separate blocks: a classical signal detector, 1, which does not perform any evaluation operations, and a measurement block for the parameter Θ, 2, (Figure 1b).

We shall now suppose that the a priori probability of the absence of a signal is equal to zero, and correspondingly, the a priori probability of the presence of a signal is equal to one: $p_0 = 0$, $p_1 = 1$. In this case, the decision making rule will have the form:

$$I_0\left(\frac{\sqrt{a_1^2+a_2^2}}{\sigma^2}\right) - \frac{\Pi_{11}\frac{1}{2\pi}\int_0^{2\pi}(\hat{\Theta}^* - \Theta)^2 e^{\frac{1}{\sigma^2}\left(\sqrt{a_1^2+a_2^2}\right)\cos\left(\frac{\pi}{2}-\varphi-\Theta\right)}d\Theta}{\Pi_{01}} \underset{\gamma_0}{\overset{\gamma_1}{\gtrless}} 0.$$

This rule recommends dispensing with measurement if the signal passage losses prove to be less than the losses due to imprecise evaluation.

The primary difference between the device synthesized here and devices which perform similar functions, but in which the detector and measurement unit are constructed independently of each other, consists in the fact that in these traditional structures there is no block for evaluating the a posteriori dispersion of the parameter Θ, which characterises the measurement accuracy, assuming that a signal is present. Information concerning the accuracy is introduced into the threshold stage for fine setting of the threshold, which thereby proves to be dependent on the observation results.

There is a common section, included in traditional structures for detectors and measurement units, which are synthesized independently, in the structure synthesized here for the simultaneous detection of a signal and the measurement of the angle of incidence of the wave.

In the special cases where the elements of the loss matrix are specially chosen, the structure of the device breaks down into the classical measurement and

and detection blocks. For the case of the reliable presence of a signal, in the receiving process, the resulting algorithm recommends dispensing with the measurement if the losses from signal passage prove to be less than the losses due to imprecise estimation.

The synthesis carried out here for a radio direction finder which realizes the operations of detection and measurement simultaneously, led to a more complex structure, which differs from the structures traditionally employed. For this reason, it is important to evaluate the gain resulting from the joint optimization of both operations, and to indicate the conditions under which this gain proves to be substantial from a practical viewpoint.

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ACCOMPLISHMENTS, GOALS AND ORGANIZATION OF THERMAL POWER INSTRUMENTATION CONSTRUCTION INDUSTRY DISCUSSED

Moscow PRIBORY I SISTEMY UPRAVLENIYA in Russian No 9, Sep 77 pp 3-5

[Article N.S. Ivan'shin, general director of the 'Teplokontrol'' Production Association: "On the Road to Efficiency and Quality"]

[Text] In the resolutions of the 25th CPSU Congress, the Soviet people, in all their greatness, are confronted with a grandiose picture of a new stage in the life of our nation. The Ninth Five-Year Plan became a solid foundation for further progress. The workers of the Kazan' Order of the Red Banner of Labor Production Association, "Teplokontrol'", completed it in a meritorious manner. We shall give only some of the data here. The five-year plan for the production output of the collective was met ahead of schedule, and above plan production in the amount of 7.6 million rubles was realized. Over the last five years, the volume of production has increased by 79%, where 91.2% of this growth was obtained as a result of an increase in labor productivity, which grew by 67.6%, where 63.1% was specified in the five-year plan. The production of cultural, personal and household goods increased by four times over this period. The technical level of production, the scale of overall mechanization and automation of the production processes, and the yield on capital increased.

Kazan' instrument builders have also worked well in the first year of the 10th Five-Year Plan. The plan for the volume of production in 1976 was completed by the association collective on December 28th. Production in the amount of 930,000 rubles above the plan was realized. The production volume, as compared to 1975, increased by 8.7%, and the entire increase in production was obtained through a growth in labor productivity. Plan assignments for income and profitability were met, and the above plan savings from the reduction in the production cost of goods production amounted to 997,000 rubles. The production of 14 new types of instruments was mastered for the purpose of providing the national economy with more refined instruments for the monitoring and control of technological processes.

Now, the workers, engineering and technical employees, and white collar workers of our association, just as all the Soviet peoples, are living and working under the enormous influence of the historic resolutions of the 25th CPSU

Party Congress and the October (1976) Plenum of the CPSU Central Committee. The speech of the general secretary of the CPSU Central Committee, L.I. Brezhnev, to the October Plenum, and the decree of the CPSU Central Committee, the USSR Council of Ministers, the AUCCPU and the Komsomol Central Committee, "On All-Union Socialist Competition to Increase Production Efficiency and Work Quality, and to Successfully Complete the Assignments of the 10th Five-Year Plan", generated a new wave of labor enthusiasm. In responding to the tasks set for them, the workers of the association are expressing a firm resolve to implement the resolutions of the 25th Party Congress, to carry out the assignments of the 10th Five-Year Plan, and to celebrate the 60th Anniversary of Soviet power with labor successes.

The basic directions for the development of the national economy of the USSR during 1976 - 1980 provide for advanced rates of development in the instrument construction sector. In this regard, the collective of our association is faced with solving large and complex problems.

The absolute growth in the production output of instruments and cultural, household and domestic goods by the association will be significantly greater than in the previous five-year plan. Where the increase in the production volume of goods in this five-year plan will be 1.4 times overall, the production of differential bellows manometers and transducers for high capacity power units, which are enjoying special demand by consumers, will increase by more than 2.5 times by the end of the five-year plan. The output of general industrial, miniature manometers in a 60 mm diameter package will increase from 4.5 to 6.3 million units per year, and a complex of new manometers of increased reliability will be completely mastered at the same time to replace the type MT-1-4 technical manometers. The production of autorecording and display manometric thermometers and other instruments will also increase significantly, as will that of cultural, domestic and household goods (by more than 1.6 times).

We must create and master the series production of a large number of instruments, based on new measurement principles, and which use new sensitive elements and microelectronics. The basis for starting this was our mastery of semiconductor, gauge pressure measurement transducers of the "Kristall" type. Thus, the issue is not only one of increasing the rates of production and providing for a growth in the volume indicators, but also one of significantly increasing the technical level, quality, reliability and service life of the products being produced.

The most important condition for the successful resolution of the economic and social problems of the 10th Five-Year Plan is an unswerving growth in labor productivity and a sharp increase in public production efficiency.

The workers of our association, in setting their own limits for 1977, the second year of the new five-year plan, have resolved to provide an annual growth in production volume of 10.1% over 1976, and to obtain the entire volume of the production increase as a result of increasing labor productivity, and to complete the annual plan for product output by December 29th.

In solving the problem of increasing the labor productivity and turning the 10th Five-Year Plan into a five-year plan of efficiency and quality, we have comprehensively analyzed all the possibilities and reserves and have given primary support to accelerating scientific and engineering progress. Included in the complement of our association is the Central Project Planning and Design Office for Thermal Power Engineering Instrument Construction and Automation Equipment (TsPKB "Teplopribor"), which has highly skilled personnel and a well-equipped technical base at its disposal, because of which, the timeframes for the development and introduction into production of progressive technological processes and new instrumentation engineering is successfully being reduced to a minimum. In the 10th Five-Year Plan, the collective of the TsPKB [Central Project Planning and Design Office] will carry out some 100 scientific research projects, among which, the main plant of the association will master the production of more than 40 types of new industrial instruments.

Specialists of the "Teplopribor" TsPKB, in cooperation with workers of scientific research institutes and the production sector, are now working on increasing efficiency and quality in their research and experimental design work. All of the problems, on which our TsPKB is to work, are of great national economic importance. Thus, for example, a coordinated plan provides for the development of new differential bellows manometers, which come up to the state of the art. They will replace the DSS and DSP instruments which are being series produced at the present time. Also being developed are strain gauge transducers for pressure drops with sensitive elements designed around a silicon-on-silicon (KNK) structure, having a high degree of precision, high metrological parameters, reliability and a wide range of working temperatures.

The development of a complex of indicating signaling instruments for the measurement of temperature, gauge and vacuum pressures in standard and explosion proof designs has also been completed. These instruments are intended to replace the TPP-SK, TPG-SK, TPP4-III signaling thermometers, signaling manometers and vacuum gauges, which have been produced up to now, and type MP, VP, MVP4-III, MP, VP, MVP4-IV compound vacuum-pressure gauges, as well as a number of signaling instruments being produced by the Tomsk Manometer Plant.

In 1976, based on joint developments by the "Teplopribor" TsPKB and the NIIteplopribor [Scientific Research Institute for Thermal Engineering Instrumentation] (Moscow), production was mastered for a complex of standardized pneumatic transducers for the measurement of absolute and gauge pressures, for compound vacuum-pressure gauges, as well as temperature measurement in precision classes 0.6 and 1.0. These instruments come up to the world state of the art and are the most promising designs. On the whole, the products list of differential manometers will be completely renewed over the five-year plan, the products list of manometric thermometers will be 93% renewed, and the group of instruments for pressure measurement will be 84% renewed. Taken into account in the last figure is the large volume of strain gauge transducer designs using KNK [silicon-on-silicon] and KNS (silicon-on-sapphire) structures.

The production mastery of new instruments, and the removal of obsolete instruments from production will produce a great economic effect for the national economy and allow the collective of the association to increase the output of instruments bearing the state seal of quality by more than two times by the end of the 10th Five-Year Plan.

Simultaneously with the creation and production mastery of the large number of new, refined instruments, we are implementing large-scale measures to step up production based on its technical retrofitting, the introduction of progressive technological processes, and comprehensive mechanization and automation of the primary and auxiliary operations. With the broad participation of workers and specialists, we have developed plans for technically developing and increasing the efficiency of production, as well as for the social development of the collective during 1976 - 1980. In them, considerable attention is devoted to the creation of comprehensively mechanized shops and sections, the renewal of obsolescent and physically worn out equipment, the introduction of automated and semiautomated equipment, machine tools with numerical program control, sets of equipment complexes, equipment for automated assembly operations, modernization of the existing equipment fleet, and improving the coefficient of its interchangeability. In particular, in this five-year plan, 10 comprehensively mechanized shops and sections, 12 mechanized conveyor and flow lines will be created, more than 50 units of automated and semiautomated equipment, specialized and ganged machine tools, 50 semiautomatic and mechanized installations and equipment for monitoring, testing and adjusting parts, assemblies and instruments will be introduced. Considerable attention is being devoted to the mechanization of lift and transport, loading and unloading, as well as warehousing operations. Some three warehouses will be mechanized, 10 crane rails will be installed, and a suspended, mechanized monorail track will be created between the set-up shops and the mechanical shops.

Such progressive technological processes as the hot stamping of parts with minimal tolerances for machining, and the fabrication of parts by pressure die casting will also undergo further development, and plastics and powder metallurgy, cold extrusion, etc., will be widely introduced.

Planned for introduction in production in the 10th Five-Year Plan are 60 types of plastic parts, 75 types of parts made by hot stamping, and 40 types of castings obtained by pressure die casting; the volume of the use of parts made of metal powders will reach six tons annually.

By 1980, the specific weight of progressive technological processes in the overall labor requirement for the fabrication of parts will be brought up to 85%, something which will allow us to save more than 320 tons of ferrous and nonferrous metals over the five-year plan, a large number of tools and auxiliary materials, and to reduce the labor intensity of the instruments being produced by more 497,000 man-hours.

The implementation of these measures will allow us to increase the level of production mechanization and automation from 73 to 80.5%, decrease the

percentage of manual labor from 26 to 19%, save the labor of 2,690 workers, and will yield an economic effect of more than 2,077,000 rubles.

The collective of the association is constantly working on the development of ASUP's [automated production control systems]. The number of problems which are being solved by the information and computer center (IVTs) has increased a great deal, while the level of mechanization of computational operations in management has reached 50%. In operation at the association IVTs are two second generation computers, and the third generation M-4030 computer complex and "Itekan-2M" automated graphical unit were installed in 1976. There are three complexes of punched card/tape machines, four sorting machines, 45 peripheral equipment complexes and more than 140 units of various auxiliary equipment.

Problems related to the technical and technological preparation for production, operational-production and technical and economic planning, material and technical supply, marketing the finished products, the movement of personnel, and bookkeeping are solved by means of computers. We are right now mastering a large volume of problems on the M-4030 computers using packages of applied programs and a data bank, something which will make it possible to obtain the requisite information in a more operationally timely fashion and with greater accuracy, and will significantly expand the scope of the problems which can be solved in production management and in increasing its efficiency.

The 25th CPSU Congress gave the same priority to the problem of increasing public production efficiency as to a key problem: increasing production quality and all work quality as a whole. In our association, this has become a subject of universal concern and the primary contents of socialist obligations.

In 1972, we introduced a system for labor and product quality control (UKTP) which is a further development of the system for defect-free product manufacture and its delivery to the technical control division with the first claim. In the past year, we decided to refine this system. It now takes into account the experience of leading enterprises of the L'vov oblast' in quality control, approved by the CPSU Central Committee, and takes the form of a complex of goal directed actions to establish, assure and maintain an optimum level of quality in all stages of product formation: planning, production preparation, production and operation.

The comprehensive system for product quality control (KSUPK) is an integral part of the management of a production association. It is realized on the basis of the management principles for socialist public production and encompasses all aspects of the activity of the association: the organizational, engineering, economic and instructional.

The primary task of the KSUPK is the implementation of a uniform technical policy in the association to assure a high technical level and quality of the products being produced. The organizational and procedural bases for its functioning are the enterprise standards (STP), which, being an integral part of the State Standardization System, acquire the force of law. The enterprise

standards are developed on the basis of state and divisional engineering, standards and procedural documents on questions of quality as applied to specific production conditions. Those services to which the various standards apply develop the STP's in timeframes established by the general director of the association; the coordination of the work and monitoring the proper execution are realized by the standardization and normalization division. In 1976, 26 STP's were developed and introduced, while 7 standards are now in the implementation stage.

The most important function of the KSUKP is the planning of the quality increase in the products being produced, both for the long term and in an operationally timely sense. The first includes plans for the production mastery of new types of instruments and automation equipment, their submission for state certification, as well as for the development and introduction of standards; the second includes the monthly plans for increasing the quality of labor and production in the shops and divisions, measures to eliminate individual defects, the realization of the personal creative plans of engineering and technical workers, etc.

The monthly plans to increase the labor and product quality of the shops and divisions are drawn up on the basis of the long term plans and additionally incorporate the following normative indicators: the increase in production volume delivered with the first claim; the reduction in losses due to rejects, complaints and claims by customers, as well as the return of products from the user-shops.

The plan norms for these indicators are established in a differential fashion depending on the results actually achieved by the particular shop in the preceding period, taking into account the established figures, are signed by the chiefs of the technical control divisions and production, are approved by the general director of the association and are forwarded to the shops and divisions no later than five days prior to the beginning of the plan period.

The basis for quality control is a well-functioning monitoring system and information on labor and product quality. Its organization at all stages of the shaping of quality is determined to a decisive degree by the correctness and efficiency of the controlling action.

Accounting for work accomplished in accordance with the KSUPK, and the documentation and presentation of information in the shops is carried out in the office of shop control (BTsK) and in the divisions by authorized agents who confirm the order for the association. Information on product quality, in accordance with the structural-informational scheme, arrives at the quality control office of the technical control division of an association, where it is processed and the coefficient of labor quality (KKT) is computed for the shops and divisions.

The "ASU-kachestvo" ["Automated Control System for Quality"] subsystem is being introduced for the purpose of providing for operational timeliness and reliability of the quality control information. A Day of Quality Control is

held each week by the general director of the association, during which the work totals are compiled for the week and an evaluation is made of the labor quality of the collectives of the shops and divisions in accordance with the KKT level they have attained. Also planned here are steps to eliminate the defects detected.

The quality coefficient, which is determined on the basis of the totals for the work of a shop or division during a month, is one of the basic indicators for the management activity of a subdivision. The size of the bonus award for meeting the plan technical and economic indicators depends on its magnitude. The KKT level which is achieved is taken into account in arriving at the totals for socialist competition. Category place awards are given to shops and divisions in the case where the KKT is no less than 0.8. First place can be awarded to collectives of shops and divisions which have a KKT of no less than 0.9. If the collective of a shop or division has a KKT lower than 0.9 but no less than 0.8, it can receive second or third place.

The comprehensive system for product quality control [KSUPK] provides for the wide-scale development of the forms of individual competition for the output of products of excellent quality. The production shop foremen, in whose sections the products delivered with the first claim number more than 95%, receive a monthly bonus of 10% of the material incentive funds. Workers, who have for a long time (no less than six months in a row) delivered the product with the first claim, are presented with a personal stamp, and along with the maximum award, which is established for delivering the products with the first claim, they are paid an additional bonus in the amount of 5% of the monthly salary from the material incentive fund.

The personal stamp is presented during the public Day of Quality Control as a symbol of special trust. It frees the worker from turning the products to the technical control division, something which increases his responsibility for product quality. The right to deliver products without presentation to to the technical control division has been achieved by about 610 leading production workers.

The next step in moral and material incentives for high quality product output is attaining the honored title of "Excellent Quality Worker". This title can be received by workers who work for no less than a year with a personal stamp, strictly observe technological and labor discipline, and do not have any violations of public order. The title, "Excellent Quality Worker", is awarded by the joint decision of the trade union committee and the administration, and is documented with an order for the association. The worker to whom this title is awarded, is presented with a diploma and a financial award of 50 rubles at the regular technical conference. At the present time, this honor has been attained by 75 leading production workers.

The comprehensive system for labor and product quality control provides for the constant inculcation of a sense of responsibility in the workers for the quality of the work performed, a communist approach to labor, as well as a sense of pride in their own plant and the honor of the plant brand.

In speaking before the collective of the Moscow Automobile Plant imeni Likhachev, L.I. Brezhnev stated: "Literally everything influences quality: the adjustment of a machine tool, and the characteristics of the materials, and the accuracy of the blueprint, and a clear cut chain of command. All of this is true. But at the sources of each of these factors are the specific performers. Consequently, in the final analysis everything reduces to the good conscience of the people, to the quality of their work. The conscience of each worker, whether he is a communist or a member of the Komsomol, or even not in the party, should answer for the plan, for the uninterrupted operation of all production lines, and for product quality."

Yes, it is specifically people who are at the center of the matter, at the center of any system. For this reason, along with purely production engineering problems, we are devoting constant attention to working with people, training and educating personnel, creating more favorable working, living and training conditions for them, and drawing all workers into the socialist competition and getting them behind a communist approach to labor.

Almost all workers are included in socialist competition. The overwhelming majority of workers work according to personal obligations, while the engineering and technical workers work according to personal creative plans. The collectives of 21 shops, 32 divisions, 68 production departments and 96 brigades have won the honored title of "Collective of Communist Labor". They are now fighting persistently for an increase in production efficiency and work quality, for the successful completion of the plan assignments for 1977 and to meet the 60th Anniversary of the Great October Revolution in a worthy manner.

The workers of our association have ardently supported the patriotic iniative of Moscow workers in a "Workers' guarantee of quality in the five-year plan". The first to respond to this initiative were the fitters for mechanical assembly operations of the production section of senior foreman A.I. Svetov, and the members of the famous brigade of N.I. Bakanov from the mechanical shop. The collectives of the 5th, 8th, 19th and 11th shops, and the engineering and technical workers of technical services followed their example. The essence of this competition is work at a regular tempo matched among all sections, the striving to create work conditions which promote high productivity for all workers engaged in a single technological cycle, and the providing for excellent quality of the products being produced. More than 200 "Teplokontrol'" workers, competing in the "Worker's guarantee of quality" collectives, are now achieving high results.

In 1976, on the day off devoted to communist labor, lathe operator of outstanding quality, S.M. Musin, who was awarded the Order of Lenin for achievements in the Ninth Five-Year Plan, came forward with a valuable initiative: a personal plan to complete the 10th Five-Year Plan in 3.5 years. In speaking to a rally of shock workers for communist labor at the association, he said: "I have carefully studied all of my own capabilities, and am firmly convinced that I will complete my personal five-year plan in 3.5 years." He called on all workers of the association to include themselves in the competition

under the slogan, "The Five-Year Plan -- Ahead of Schedule". At the present time, 3,500 workers of the association are competing under this slogan. Initiator S.M. Musin and his followers, lathe operators N.N. Mikheyev, Yu.I. Kachalkin, adjuster D.K. Mordanova, forge operator V.V. Volkov, and others, having completed their personal plans ahead of schedule in the first biennium, have started to work on the second biennium of 1977.

Komsomol members of the asembly shop have supported a remarkable initiative by Leningrad komosomol members, "60 Weeks of Shock Labor for the 60th Anniversary of the Great October Revolution". They are the first in our association, who, having taken on high socialist obligations have decided to stand a 60 week shock work watch, devoting each week to the corresponding year of Soviet power, and to compete for the right to sign the report of the Leninist Komsomol to the Central Committee of the CPSU. They are working according to the principle: "For each week, the highest labor productivity, excellent product quality, and high labor discipline". Now, the overwhelming majority of young instrument builders of the association are included in this movement, and are standing the 60 week shock work watch.

The comprehensive system of product and labor quality control, multiplied by the self-sacrificing labor of the collective, is producing positive results. In the past year, 64 types of products have been produced with the state seal of quality. In December of 1976, this seal was awarded to eight mroe types of autorecording thermometers and manometers. Now, 20% of the overall volume of the commodity production of instruments is produced with the seal of quality. The percentage of products delivered with the first claim by the technical control division grew from 95.5 to 97.1%, and complaints and reject losses decreased markedly.

In the 10th Five-Year Plan, we are planning to increase the volume of production realized in the highest category from 20% in 1976 up to 46.2% by 1980, to introduce 20 state divisional standards, and to bring the deliveries of products by the technical control division with the first claim up to 99%.

However, if one considers what has been achieved from the viewpoints of the highest requirements of the 25th Party Congress, then it must be said that in the 10th Five-Year Plan, we are still faced with considerable and persistent work on the further refinement of the KSUPK, as well as on the constant increase in the technical level, quality, reliability and service life of the products being produced by means of improving the operational quality of all links in production and management. It is now specifically on this that the efforts of the party organization, economic management and all workers of the association have been concentrated.

The work totals of the association for the first biennium of 1977 attest to the considerable upswing in labor and public activity of the association workers. The plan for product output is being met, and the volume of production has been increased over that of the corresponding period of the past year, where the entire increase was obtained through increasing labor productivity. All of this instills in us the certainty that the tasks set for the association collective will be carried out successfully.

We attribute considerable significance to the study and dissemination of advanced production experience, and the introduction of scientific and engineering innovations. The cooperation of the association with the USSR VDNKh [Exhibition of National Economic Achievements] is playing a great part in this plan.

The "Teplokontrol'" production association is a permanent participant in the USSR VDNKh. Our instruments are demonstrated annually in the "Machine Construction", "Electrification of the USSR", and the "Chemical Industry" pavilions. The association also participates in special exhibits held at the USSR VDNKh. We were participants in the "Automated Production Control Systems" exhibition. The association was awarded the diploma of the USSR VDNKh, Class II, for the development and introduction of the "ASU-Teplokontrol'", while 23 of our workers received medals from the USSR VDNKh.

Young designers of the "Teplopribor" central planning and design office were participants at the NTTM-74 exhibition, which was held at the USSR VDNKh. Designers V.A. Gizzatova and A.S. Groshev were awarded bronze medals of the USSR VDNKh for the development of a dual pointer manometer, the M22P, and an instrument for recording a pressure-path diagram, the MTS-53, ZZT, which were shown at this exhibition.

USSR VDNKh medals were awarded to 35 association workers. Considerable interest was generated among the association specialists by those seminars, schools, and specialized exhibits which fit our speciality, and which are held by the USSR VDNkh, and every year we send a group of specialists and leading workers of the association to the USSR VDNKh to participate in such activities and borrow from advanced experience.

The work experience of the best labor collectives and innovators is being studied in 150 schools of communist labor and advanced experience. By studying and widely employing advanced production and engineering experience, by mobilizing internal reserves, the workers of the "Teplokontrol'" Kazan' Production Association will do everything to successfully carry out the assignments set in the historic resolutions of the 25th CPSU Congress, and to meet the 60th anniversary of the Great October Revolution in a worthy manner.

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DEVELOPMENTAL PROSPECTS FOR MICROELECTRONIC TECHNOLOGY IN INSTRUMENT CONSTRUCTION

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[Article by the general director of the "Temp" microelectronics scientific production association, P.D. Litvinenko" "Microelectronics Technology in Instrument Construction"]

[Text] The broad product mix in instrument construction determines the diversity of the directions being taken in the design and technological sector of microelectronics. One of the main directions is hybrid, film technologies for the creation of integrated circuits (IC's) for special applications and microassemblies.

Hybrid, film technologies are distinguished by the extensive possibilities for the realization of IC's as regards the precision of the elements, the levels of signals, and the type of functions performed by the circuit. Modern fabrication technology for hybrid, film IC's is characterized by comparatively low costs for the preparation of production and considerable flexibility, i.e. it is possible on this basis to develop and fabricate a broad products list of special applications IC's, necessary in the production of modern instruments and computer equipment. Finally, hybrid, film technologies permit the creation of large-scale, hybrid integrated circuits (BIS) [hybrid LSI] with a practically unlimited level of integration, as compared to semiconductor LSI.

Hybrid circuits are designed using two technological approaches: thin film, and thick film.

Thin film technology is being developed primarily in precision instrument construction, something which is explained by its high resolution capabilities, and the precision and stability of the circuit components. This type of technology does not have any competitors in the production of precision resistor matrices, voltage dividers, high quality operational amplifiers, voltage regulators, as well as specialized amplifier circuits and measurment circuits for monitor and control instruments. Thin film technology will also play a

leading role in the production of digital-analog and analog-digital converters, used in the majority of equipment complexes in modern instrument construction.

Thick film technology, which is distinguished by a smaller production preparation cycle and less complex equipment, is used for the fabrication of relatively simple circuits for numerical program control devices, computers, and a number of analytical instruments.

Methods of multilayer commutation on a dielectric substrate of sitall [ceramic glass, similar to pyroceram] or polikor, methods of assembling and installing chips with rigid leads, new methods of fabricating "color" and multilayer photographic templates are being developed and introduced in the area of thin film technology in industry; the possibilities of using new dielectric, semiconductor, resistive and conducting materials are being studied. Work will be continued on the introduction of methods of automated laser alignment of thin film elements.

Considering the diverse product mix in the production of hybrid LSI circuits in the industry, as well as their primary technological characteristics, such as the level of integration, reliability, overall dimensions, simplicity and economy of the technological process, the possibility of automating design and fabrication, one can say that a comprehensive thin film technology based on the use of organic dielectric films most completely answers the requirements of the industry. This technology has been proven out in the fabrication of complex, high reliability circuits, having the maximum level of integration achieved at the present time.

Operations are being planned for the production mastery of a variant with a triple layer layout for circuits with an extremely large number of intersections (up to several thousand). A promising trend in thin film technology is also the use of electron beam methods of treating film materials. The use of these methods, along with electron beam and ion plasma methods of applying thin films, are opening up paths to the comprehensive automation of the processes of manufacturing hybrid film IC's.

Prospects for thin film technology are the expansion of the range of useable materials and the development of the technology for multilayer structures. The possibilities of increasing the precision of thin film structures through the introduction, for example, of photosensitive materials are being studied.

Semiconductor technology is the second main direction being developed in the microelectronics sector. This technology is characteristic of mass produced products: keyboard type electronic calculators (EKVM), electronic watches, microprocessors and memories.

For all of the devices enumerated above, it is technically and economically expedient in instrument construction to fabricate special IC's with a high level of integration based on the technology of MOS structures (metal--dielectric--semiconductor). The basic merits of MOS structures are the simple

technology for their formation and the increased packaging density. MOS structure technology permits the realization of the most complex logic functions on one or several LSI chips with a high degree of reliability and high technical and economic production indicators.

Three forms of MOS structure technology are being mastered: p-channel, n--channel, and CMOS technology (complementary structures). The simplest p--channel technology provides for the requisite operational speed, power consumption, threshold voltages, slope of the characteristic, leakage currents for such circuits as IC's based on homogeneous structures, and four-phase logic IC's for EKVM's. The method of fabricating a p-channel MOS IC is the usual planar technology with a minimum number of high temperature diffusion and oxidation operations, and precision photolithography operations.

Industrial experience attests to the fact that the majority of memory device circuits are more expediently manufactured using n-channel MOS technology, which permits obtaining circuits with an increased operational speed, which are necessary for control computer complexes. The introduction of such technology requires the mastery of epitaxial technology in the industry.

Integrated circuits intended for crystal controlled electronic wrist watches, which, as a rule, consist of a master crystal oscillator circuit, a voltage divider and control circuitry should be distinguished by a high level of integration, minimum power consumption, increased precision and reliability, as well as a low power supply voltage. These requirements are basically satisfied by the technology of CMOS structures, which are characterized by the presence of n-type and p-type channels. This technology is many times more complex than the usual planar and planar-epitaxial technology. It is sufficient to note that the number of photolithography operations with the superimposition of the layers grows to 10 - 12 in this case.

The search for new concepts for the creation of semiconductor LSI circuits has led to the appearance of a completely new circuit engineering and design technology: integrated circuits with injection or combined transistor logic (AND^2 logic).

The possibility arises in AND^2 logic circuits of dispensing with the traditional method of supplying power to the base and collector circuits of the keying transistors of the logic gates in the IC through resistors, which limit the current, consumed from the power source. In this way, resistors are successfully eliminated from the electronic circuit, something which promotes a substantial increase in the component layout density on an IC chip, and permits a significant decrease in the product of the delay time times the power dissipation. The successful application of injection circuits in the development and manufacture of single chip microprocessors and memory circuits for control computers, with capacities of 8K, 16K and more bits, is to be anticipated. Integrated AND^2 logic circuits completely meet the requirements placed on watch circuits.

Investigations are going forward in the sector into the use of the principles of physics in the design of microelectronic instruments and computer equipment. We shall cite only a few of these devices: memories based on flat and cylindrical magnetic domains, which will be capable later of replacing the external memory blocks of computers; optomicroelectronic IC and matrices, the application of which with the optical input and output of information will permit the elimination of all commutating devices in computers, and increase the operational speed and reliability of the latter; displays based on liquid crystals, electroluminescence and electrochemical principles.

In connection with the accelerated pace of development of instrument construction and computer engineering based on microelectronics, the growth in the product mix, the increase in the functional load on products, the expansion and increasing stringency of the requirements placed on the output parameters of special applications IC's which are being manufactured, one of the first priority problems is becoming that of automating all stages of IC creation: planning, fabrication and quality control. The urgency of a solution to this problem is unquestionable, however, the introduction of automation into the design, fabrication and quality control of IC's will take place in an uneven fashion.

It is possible to conditionally differentiate five stages in the automation of both semiconductor LSI circuits and hybrid IC's and LSI circuits. In the first stage, the functions of design and fabrication of IC's and LSI circuits are broken down into the operations of tracing the set of large scale photographic masters on a precision, automated coordinatograph. The coordinatograph is controlled from a punched tape, or directly from a computer, by means of programs which are result of machine calculation of the structure, parameters and topology of the IC's and LSI circuits.

In the second stage, the automation of the production task reduces to the fabrication of working copies of the photographic masters, the semiconductor and film structures on maximally automated installations, which are put together into comprehensive equipment lines. The introduction of such lines occurs simultaneously with the introduction of automated assembly and installation lines, and the quality control equipment using computers.

The subsequent stages presuppose the use of beam methods of treating the templates (the third stage) and semiconductor and film structures (the fourth stage). The transition to the machining of the materials by means of electron and ion beams, and laser radiation, permits the creation of comprehensive automated production lines for IC's and LSI circuits, including the operations of assembly, installation and quality control.

Finally, the systems for the automated design, fabrication and quality control will be combined into a single automated production complex, controlled by computers and which necessarily incorporates automated control systems for the technological process and an automated system for statistical monitoring.

Both of these systems will have feedback with the planning system, so that based on the results of measuring the parameters of the technological process and the output parameters of the circuit, both the technological process itself and the electrical and design characteristics of the IC's and LSI circuits will be corrected.

In conclusion, we will note that, as can be seen from what has been said above, a comprehensive approach to the solution of the problems of designing and producing microcircuits is required, where technological support of the industry will play the determinative role.

The development of microelectronics technology in the industry depends basically on the level of production of special technological equipment, special accessories and tools. The creation of a machine construction base in the industry for the manufacture of the special technological and monitoring and measurement equipment provides the conditions for the wide scale introduction of microelectronics into instrument construction.

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DEVELOPMENTAL TRENDS IN THIN FILM TECHNOLOGY

Moscow PRIBORY I SISTEMY UPRAVLENIYA in Russian No 9 Sep 77 pp 52-53

[Article by engineers I.N. Pervunitskiy and O.D. Sorokoletov]

[Text] Hybrid, thin film technology, which assures high precision characteristics of microcircuits and the possibility of realizing a broad products list of devices [1, 2], has been selected as one of the most important technological directions for the development of special applications microcircuits. Hybrid, thin film technology is based on the combining in one hermetically sealed package of chips with the thin film passive part of a circuit, the unpackaged semiconductor integrated circuits (IC's) of any level of integration and the microminiature outboard mounted passive components.

The passive part of a microcircuit can be fabricated by one of the well-known methods: the masking method using separate, continuous or combination vacuum deposition; single or double photolithography; photolithography with galvanic growing (combined technology); photolithography with electrochemical anodizing (tantalum technology). Predominantly employed for the production of special applications, hybrid IC's (GIS SP) is the method of double photolithography, based on the sequential selective etching of the layers of a multilayer film structure, which is obtained beforehand in a vacuum. This method provides for a high circuit layout density, a precision in the fabrication of film resistors without adjustment of no worse than ±5%, high productivity, and rapid resetting of the equipment for the production of a broad products list of circuits by means of replacing only the set of photographic templates.

The further refinement of the fabrication technology for special applications, hybrid IC's entails improving the electrophysical parameters of film elements by the application of new materials and refined technological processes, as well as the development of automated equipment to reduce the cost of special applications, hybrid IC's under conditions of small series production.

The step by step refinement of the technology provides for the priority introduction of the method of ion-plasma vaporization for the formation of multilayer film structures, since this method permits obtaining a film of practically any of the materials used in thin film technology, and in this case, one with high characteristics [3]. Ion-plasma vaporization provides for high

reproduceability of the chemical composition of films with a nonuniformity in the thickness on a substrate with dimensions of 60 x 48 mm of no worse than ±1%.

Increasing the quality and manufacturing precision of high precision, thin film resistors for special applications, hybrid IC's entails the application of the ion etching method in place of chemical etching. In this case, the difficulties of selecting the etchants to process thermally stabilized resistive layers, and the harmful effect of chemical reagents are eliminated [4]. The introduction of ion-plasma vaporization, in conjunction with ionic etching, will permit bringing the error in thin film resistors down to 0.005 percent, down to the level of printed circuit precision resistors.

Plasma-chemical cleaning, the unquestionable advantages of which over the chemical method include reducing the number of technological operations, imporving the purification stability and increasing the output of suitable products, can find wide applications in the production of special applications, hybrid IC's [4]. Dry plasma-chemical cleaning, for example, the plasma-chemical method of removing the photoresist by means of an HF plasma in a mixture of halogen carbide and oxygen, eliminates the use of toxic solvents.

Promising for the growth of special applications, hybrid IC technology is the development of electron and ion technologies for the formation of film elements by means of the direct local and selective action of electron and ion beams with computer control of the process [3]. Electron-ion technologies permit excluding not only individual operations from the process, but also entire technological sections (the fabrication of the photographic templates and the photolithography process), because of which, labor intensity and the cost of manufacturing the microcircuits are reduced. Electron-ion technologies make it possible to solve a basic problem in the production of special applications, hybrid IC's: reducing the cost of microcircuits for the case of a small production volume and a broad products list by means of introducing machine methods of hybrid integrated circuit design and complete automation of the manufacturing process.

One of the possible variants of electron-ion technology takes the form of the following sequence of operations: the precipitation of a continuous resistive film by ion-plasma vaporization; the formation of a protective mask by electron beam polymerization of hydrocarbon vapors by means of a sharply focused electron beam controlled by a computer; ion etching of the resistive layer; plasma chemical removal of the protective mask; precipitation of the continuous structure of the conducting layer by means of ion-plasma vaporization; formation of a protective mask by electron beam polymerization; ion etching and plasma-chemical removal of the polymer protective mask. Thus, using electron-ion technology, it is possible to manufacture the entire passive part of a special applications, hybrid IC in one technological cycle without unsealing a vacuum system on a technological production line, something which promotes an increase in the reliability of the microcircuits, a curtailment of the duration of the process and provides for complete automation of the process.

Problematical questions and future prospects for the development of special applications, hybrid IC technology are likewise related to a transition to large-scale, hybrid integrated circuits (BGIS) [hybrid LSI] and to microassemblies of a high level of integration, the introduction of which into instrument construction will provide for the highest technical and economic indicators, and will permit an increase in the production volume of electronic instruments by more than two times in the already existing production facilities. The transition to the new component base will make it possible to significantly reduce the production cost of instruments, by decreasing their metal consumption, reducing the number of printed circuit boards and plug connections, and decreasing the overall cost of the electronic components.

The development of special applications, hybrid LSI circuits and microassemblies is primarily a technological problem, related to the problem of creating a reliable, multilayer layout and providing for installation density of the active components for the case of an automated assembly process.

In a number of organizations (The Design, Technological and Scientific Research Institute, the Teplopribor Scientific Research Institute, and the All-Union Scientific Research Institute for Electronic Instruments), work has started on the development of hybrid, special applications LSI circuit and microassembly technology. In particular, laboratory technology for the fabrication of analog special applications hybrid LSI circuits on polikor substrates with the simultaneous application of low resistance (chromium) and high resistance (cermet K-50S) resistive materials has been created at the Yaroslavl' Design, Technological and Scientific Research Institute. Used as the material for interlayer insulation in the multilayer layout was PAK-1 polyamide varnish with a thickness of up to 15 micrometers. The method developed here for the generation of the drawing of the insulation layer and the relatively large insulation thickness provided for high electrophysical parameters of the multilayer layout (for example, $C_{spec.} = 2 - 3$ pF/cm^2) and a high percentage output of suitable products.

The structural and technological design of special applications, hybrid LSI circuits and microassemblies of a high level of integration requires the solution of such technological problems as the automation of the process of assembly and disassembly of new materials, including that for the interlayer insulation. To realize a wide range of nominal values for thin film resistors in microassemblies, an ultralow resistance resistive material of the BrNTG-20 alloy type is required, as is a high resistance material with higher characteristics than those of K-50S cermet. Required for precision resistors with a stability of 0.01 - 0.005% are resistive materials based on rhenium, zirconium nitride and other materials.

The problem of creating a reliable multilayer layout is solved at times by using organic materials of the polyamide type for the interlayer insulation; the use of inorganic materials is also possible, such as low melting point glasses, where the configuration of the insulation layer should be generated by progressive methods, including ion or plasma-chemical etching.

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DEVELOPMENTAL TRENDS IN THICK FILM TECHNOLOGY

Moscow PRIBORY I SISTEMY UPRAVLENIYA in Russian No 9, Sep 77 pp 53-54

[Article by engineers S.A. Belousov, V.S. Kuznetsov and V.N. Filatov]

[Text] The advantages of thick film technology for the fabrication of microcircuits over the other technological approaches are: simple equipment which does not require skilled personnel, low cost and low labor intensity of the operations, a short production cycle, a high level of process automation for the fabrication of the passive part of the microcircuit, the capability and simplicity of creating multilevel circuits, and the comparatively low capital outlays for the organization of production and the short timeframe for investment recovery.

The production technology for thick film, special applications hybrid integrated circuits (GIS SP) of the first level of integration using a metal-polymer package and a ceramic substrate with dimensions of 11 x 11 mm has been worked out at the Design, Technological, and Scientific Research Institute (Yaroslavl'). A technological process for the fabrication of thick film, special applications hybrid IC's of the second level of integration, in a 209.18-1 package of an in-house design with a ceramic substrate having dimensions of 9.5 x 20.2 x 0.8 mm, has been created on the basis of this technology, and the production of microcircuits for monitor and control equipment sets has been organized.

The technology has been developed for the fabrication of thick film, hybrid special applications LSI circuits in a ceramic package with two substrates having dimensions of 24 x 36 mm. The latter work has shown that by employing insulation pastes of the PI-14 or PD-10 types based on STs-273 sitall cement, one can obtain a six layer commutating layout on each side of the plate, as well as resistors positioned on the top insulation layer. In this case, the output of suitable commutating plates (prior to the formation of the resistors) is close to 100%.

The possibility of using ceramic substrates with dimensions of 48 x 60 mm for the fabrication of microassemblies based on thick film technology has been studied. It follows from the results of the study that the value of resistors formed at any point on a large substrate falls within technological

tolerance limits. The authors consider it expedient to continue the development of the technology of installing chips on a thick film ceramic plate with groups of thin film precision resistors in the chips and to make a transition in the future to the development of the fabrication technology for functionally complete hybrid microassemblies.

The basis for microassemblies will be a ceramic plate with dimensions, for example, of 48 x 60 mm, on which a multilayer commutating layout is formed using thick film technology methods. The number of commutating layers, if they are judged based on the level achieved at the present time, can be brought up to 12 by using both sides of the substrate. On such a plate, in addition to the conductors, the film resistors and capacitors can be manufactured in a single technological process. Moreover, groups of precision thin film resistors, entire unpackaged thin film and semiconductor integrated circuits, and where necessary, also individual components in a package, can be mounted on a thick film plate.

The large volume of work on refining thick film technology is apparent from an analysis of the literature. What has been said applies in particular to materials. Specifically, the possibility of replacing precious metals by not only rare ones (ruthenium, osmium, rhodium, iridium), but also by such widely disseminated ones as thallium, titanium, nickel, chromium, molybdenum, indium, cadmium and aluminum, is being studied [1 - 11].

Conducting pastes based on molybdenum and nickel have been derived [12], which after buring-in in a reducing medium (oxygen) at a temperature of more than 900° C, provide for adhesion of the conductors to a substrate of 22KhS ceramic of more than 1,000 kg/cm^2. Such high adhesion of the conductors to the substrate makes it possible to use them as contact areas for the direct welding connection of the external leads of microcircuits. The development of hydrogen resistant sitall cements for interlayer insulation and the use of conducting pastes based on molybdenum and manganese will permit the creation of multilayer, commutation layouts with exceptionally high reliability characteristics.

A significant achievement is the development of pastes based on ruthenium [3, 4]. These pastes have better characteristics than others, while resistors based on ruthenium exhibit a high degree of stability, have a low temperature coefficient of resistance (100 · 10^{-6} 1/°C), a high moisture resistance and sustain voltages of up to 250 volts/mm.

Such resistor characteristics permit expanding the applications area of thick film technology and creating, for example, high precision and highly stable voltage dividers. The resistance of ruthenium compounds to high voltages makes it possible to use these pastes for the fabrication of hybrid IC's which have high voltage and high power output circuits.

From an economic viewpoint, of interest are communications on the substitution of inexpensive standard window glass with a melting point of 575 - 625° C for

ceramic substrates. In this case, compounds of conducting and resistive materials are used which are subjected to treatment at the same temperatures [13].

The use of plastic systems based on various epoxy and phenol resins [14] as substrates and pastes is of interest. For conductors and resistors, the functional phases are silver and carbon respectively. The heat treatment of these compositions is accomplished at a temperature of no more than 200° C. The characteristics of the components are comparable to the characteristics of standard circuits.

The sphere of thick film technology applications can be extended through the use of light sensitive compounds, or photopastes [15]. Photopastes, and the photolithography method related to them, permits the fabrication of thick film integrated circuits with a resolving capability close to the resolving capability for thin film technology, but without the use of expensive vacuum equipment and complex deposition processes.

The use of solder pastes permits the automation of the microcircuit assembly process, an improvement in the quality of the tinning of the contact areas, and increase in reliability and density of hybrid, thick film IC integration. Solder pastes are prepared on the basis of powders of low melting point solders, which contain tin, lead, silver, gold, bismuth and cadmium [12, 16]. Another basic constituent is flux. As a rule, noncorrosive and nonconductive fluxes are employed. Solder pastes are usually applied by the grid graphing method.

In the US, such an important applications area for thick film technology as high power hybrid IC's, in particular power amplifiers (100 watts), motor control systems, high power switches and other high voltage (up to 600 volts) and high current (up to 7 amps) switching devices [17] has become clearly pronounced. High power thick film circuits will find wide applications in a number of devices and in industrial automation.

The utilization of thick film technology to create plasma light displays, thermocouples, thermal printer matrices [18 - 21], should proved to be quite promising for instrument construction. Thick film plasma displays are simple, inexpensive, have a long service life and produce a bright image [18, 19]. Using a thick film thermocouple of palladium-platinum and gold-palladium alloys, one can measure temperatures in a range of 0 - 800° C with an error of 1% [20].

The technological production process for thick film, hybrid IC's has attained a high level of automation, espeically in the fabrication of the passive components. Work is going ahead on the creation of a production process automated control system for the manufacture of the passive part, and also on the automation of the assembly process. Thus, in the technological process automated control system for the manufacture of the passive part of thick film microcircuits, which was described in the literature [22], the following problems are solved: local control of the resistor burn-in operation (the control actions are being worked out), control of the preparation and application of

the resistive pastes (the information is gathered and recommendations are made), operationally timely monitoring and central dispatcher control of the production of the passive paste for the microcircuits, and automated statistical control.

The basic developmental trends in thick film technology in instrument construction are the following: the transition to the fabrication of functionally complete microassemblies and microinstruments of the fourth integration level (more than 1,000 components per plate); the replacement of precious metals in semiconductor pastes; the creation of pastes which provide for an improvement in the technical characteristics of the resistors; research into crystallizing glasses (sitall cements) for the purpose of improving the technical characteristics of insulation pastes for multilevel hybrid IC's; the creation of dielectric pastes which provide for an increased specific capacitance of film capacitors; the automation of the assembly process and the introduction of the technological process automated control system.

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GEOPHYSICS, ASTRONOMY, AND SPACE

COSMONAUTICS: ACHIEVEMENTS, PROSPECTS FOR DEVELOPMENT

Moscow PRIRODA in Russian No 10, 1977 pp 4-9

[Article by Academician R. Z. Sagdeyev]

[Text] The first artificial earth satellite was launched on 4 October 1957. On that day our Fatherland raised the flag of a new era in scientific and technical progress of mankind -- the era of the conquest of space.

We note the 20th anniversary of launching of the first satellite on the eve of the great holiday of our people and all progressive mankind: the sixtieth anniversary of the Great October Socialist Revolution. These events and dates are related to the logic of history. During a short time an agrarian, industrially backward country was transformed into a powerful industrial state capable of embodying into life the boldest dreams of mankind.

In order to proceed to investigations of space it was necessary to solve a whole series of highly complex scientific and technical problems related first and foremost to the designing and production of powerful carrier-rockets, with the development of complex processes and equipment for their prelaunching preparation, creation of unique scientific apparatus for space experiments --- instruments having a high measurement accuracy and exceptional reliability when they were exposed to a whole series of space factors. Such a task was within the power of only a country having highly qualified scientists, engineers, technicians and workers.

"Artificial earth satellites are laying the way for interplanetary travels and evidently our contemporaries were fated to be witnesses of how the liberated and conscientious work of the people of a new, socialistic society transform the boldest dreams of mankind to reality." This statement is from a TASS communication on the launching of the world's first artificial earth satellite. We are convinced of the truth of these lines by each new launching, each new "step" to the stars.

In 1957 only two satellites were put into circumterrestrial orbits. By the end of the tenth year of the space era the total number of launchings of spacecraft in the USSR had attained 617. Now the count for satellites of

the "Kosmos" series alone is approaching a thousand. And in addition there are "Polet," "Zond," "Elektron," "Proton" and "Prognoz" satellites.

It was only three and one-half years after the launching of the first artificial earth satellite when man flew into space. The first cosmonaut in history was the Soviet citizen Yuriy Alekseyevich Gagarin.

The Soviet people also won the right to apply the words "for the first time" to such events as the photographing of the far side of the moon, a soft landing of automatic stations on its surface, flight around the moon and return to the earth at second cosmic velocity, landing of automatic stations on the surfaces of the planets Venus, Mars, launching of multiplace spaceships, emergence of man into open space, automatic docking of space vehicles in orbit, and many, many other things.

There is no need for enumerating here all the events of past years. We note only that much about which man earlier could not even dream has already taken place. During a short time cosmonautics has been transformed into one of the principal directions in modern scientific and technical progress.

In a relatively short period of time satellites, spaceships and automatic interplanetary stations led to many outstanding discoveries, gave unique scientific materials which with former methods would have required long years of stubborn work.

Space investigations considerably changed our concepts concerning circumterrestrial space and established very profound relationships between the processes transpiring on the sun and near the earth. This is of enormous importance for improving meteorological forecasts, for understanding the laws of radio wave propagation and for understanding many phenomena important for man's practical activity. Only due to investigations on satellites and rockets do we now have a rather full picture of the structure of the upper layers of the earth's atmosphere.

It was found that circumterrestrial space is not a void and unstructured region, as was surmised earlier, but is filled with plasma complex in its physical properties, permeated by electric currents and magnetic fields, constituting an interrelated system. The collected knowledge became a basis for a general understanding of cosmic plasma. Now the question is even being raised of how to apply the ideas and theories developed for circumterrestrial space to other regions of space -- the sun and Galaxy, for solving cosmological problems in general.

Completely different possibilities have been opened by the use of rocket and space technology in the study of planets of the solar system. The flights of automatic stations gave to scientists more than the preceding investigations carried out during the entire history of mankind, particularly in the forming of a detailed picture of Venus or Mars. The same can be said of the moon.

The soft landing of automatic stations afforded a possibility for studying the structure of its surface, the chemical and mineralogical composition of lunar rocks. The launching of artificial satellites into orbit around the moon made it possible to carry out investigations of the magnetic field, meteor and radiation conditions in circumlunar space and gamma radiation of the lunar surface. We have been witnesses of illustrious flights of Soviet automatic stations, which, making flights from the earth to the moon and back, returned to the earth samples of lunar rock, including from a continental region of difficult accessibility. The self-moving "Lunokhod" vehicles operated on the surface of our eternal satellite.

One of the principal directions in Soviet space research is study of Venus by means of vehicles which descend into the depths of its atmosphere. A major step in the exploration of the "morning star" was the flight of automatic stations of a new type, the "Venera-9" and the "Venera-10." For the first time in the history of space conquest it was possible to create two artificial satellites of Venus and two descent modules made a soft landing in different regions of the planet and transmitted phototelevision images of its surface to the earth. Valuable information was obtained concerning the atmosphere, cloud layer and surface of Venus.

Mars proved to be a planet unique in its properties. On the surface of Mercury we find much in common with the surface of the moon. On the basis of some criteria Venus can be considered if not completely similar to the earth, at least its sister. The planets of the Jupiter group are assigned to the class of so-called giant planets with a characteristic common constitution. Mars, however, does not have analogues in the solar system.

The successes in study of the moon and planets of the solar system by means of rocket and space technology even today make it possible to understand such stages in the history of the earth as have been erased by time or have been buried at inaccessible depths.

Rockets, artificial earth satellites and spaceships have made it possible to carry different astronomical instruments into the upper layers of the atmosphere and beyond its limits. Thus, new directions in astronomical investigations appeared: submillimeter, infrared, ultraviolet, x-ray and gamma astronomy. Investigations of celestial objects in ranges of electromagnetic waves inaccessible for observations from the earth's surface led to a series of fundamental discoveries. A deepening and rethinking of our ideas concerning the universe, Galaxy and solar system is taking place.

Equally important steps have already been taken in the field of manned space flights. The flight of Yuriy Gagarin demonstrated the practical possibility of man's direct participation in space flights. His flight was of relatively short duration -- less than two hours. And now the "Salyut-4"

has already flown for more than two years. The first crew, consisting of A. A. Gubarev and G. M. Grechko, and the second crew, consisting of P. I. Klimuk and V. P. Sevast'yanov, worked aboard it and spent 63 days in space.

With each passing year there has been an increase in the importance of cosmonautics in satisfying the practical needs of mankind. Devoting the closest possible attention to the development of space research, the Communist Party and the Soviet government are striving insofar as possible to make the fullest use of space technology in the interests of the national economy. The conquest of the space zone closest to the earth made possible a radical improvement and simplified solution of many practical problems, such as communication over great distances.

Space meteorology has really become a part of our life. It has considerably broadened the possibilities of observations of the atmosphere at a planetary scale and has become an independent field of weather science.

Now space research is in the stage of qualitative changes. The period of the initial accumulation of facts, the period of "reconnaissance" has ended. The stage of systematic profound investigations has begun. Space has become a place for normal scientific and engineering-technical work. The optimum methods for such activity have already been determined. We can state with satisfaction that in investigations of the solar system it was found that the use of automatic vehicles, such as our "Lunas" and "Lunokhods," was the most progressive. Following this same approach, American scientists attained successes in the study of Jupiter using the "Pioneer" automatic stations and carried out a complex of investigations on the surface of Mars using "Viking" vehicles.

In the next ten to fifteen years it will evidently be possible to obtain detailed information concerning virtually all planets of the solar system. Here the principal research problems can be divided, to be sure extremely arbitrarily, into three classes.

The first is the origin of the solar system: how and when did our system of planets develop around the sun, how did it evolve and what will it become in the future? The answering of these questions requires new information on the planets. In addition to the general characteristics, such as mass, size, figure and period of rotation, it is necessary to understand the structure and chemical composition of the surfaces of the planets, their temperature, and also the temperatures of their atmospheres, and data on their composition. It is very important to clarify the relationship between the planetary matter and the matter in comets, meteorites and other interplanetary matter.

Another class of problems is investigation of the dynamics of the atmospheres of other planets; in particular, this is extremely valuable for terrestrial climatology. Such investigations make it possible to analyze global

movements in the atmospheres of the planets and possibly discover types of movements which are unknown on the earth. The good prospects for the creation of a general thermogas-dynamics of atmospheres of planets of the earth type are affording the possibility, in the foreseeable future, to have scientifically sound methods for the control of weather and for a reasonable modification of the climate of our native planet.

Finally, a third class is the origin of life. The most interesting object in this respect is Mars. Here the main emphasis will evidently be devoted to complex experiments, including a broad range of experiments for study of the organic chemistry of the planetary surface and carrying out purely biological investigations.

There are many promising aspects of study of the peripheral regions of the solar system and the giant planets Jupiter and Saturn. The determination of the ratio between the volatile, silicate and iron components of these planets means to take a step toward an understanding of how the protoplanetary cloud separated at different distances from the sun and under what conditions the concentration of planetary matter occurred.

The small bodies of the solar system, the asteroids and comets, hide extremely valuable information on the primary matter of the protoplanetary cloud. Precisely in the course of their investigation it will be possible to find a key to the understanding of the peculiarities of the early period in the development of the solar system.

Circumterrestrial space is also receiving attention. The main emphasis here will be on study of the totality of parameters, their temporal and spatial variations, and relationships to solar activity. For this it is most promising to use several space vehicles working in accordance with a unified program in combination with simultaneous surface observations with broad theoretical generalizations.

In solving the problems involved in the physics of the magnetosphere definite attention will also be devoted to controllable, active experiments.

Now there is every basis for assuming that the problems of investigation of distant space by the methods of exoatmospheric astronomy will come to the forefront.

The further development of exoatmospheric astronomy should evidently occur along the lines of the launching of specialized astronomical satellites working in automatic and semiautomatic regimes. Permanently operating observatories in space will also be created, with a long-term unlimited increase in their size, outfitted with means of analysis and registry of data, including on-board electronic computers. The observatories will carry telescopes which will be able to carry out measurements simultaneously in the entire range of electromagnetic waves, which will make it possible to form a full picture of the observed phenomenon.

One of the promising directions in the development of x-ray astronomy, evidently, will be the use of a focusing optical system. Together with an increase in the accuracy in orientation of a space vehicle, this will make it possible to increase the angular resolution of the observations. In turn, the solution of this problem should lead to a broadening of the class of objects accessible for observations, and to a more detailed determination of their characteristics.

A complex, but at the same time an exceptionally significant scientific and technical problem is the creation in orbit of a space radio observatory outfitted with large antenna systems and also networks of simultaneously operating extensible radio telescopes with a size unattainable under terrestrial conditions.

An important prospect for space radiointerferometry will be the realization of very large bases of radiointerferometers measuring up to an astronomical unit. This is affording completely new possibilities for investigations: determination of distances to any objects in the universe, velocities of objects, obtaining three-dimensional images, etc.

Synchronous observations will be developed, together with the interference method. In the synchronous method the clouds of plasma between the radiation source and the radiotelescope can serve as some effective lens of a cosmic scale, creating around the earth an image of the investigated source. The purpose of the space radiotelescope will be the measurement of the intensity and temporal changes of this image.

A very simple variant of a system of synchronous observations consists of two antennas with a base of variable length and direction between them. In the next stage there must be operation of three space radiotelescopes. Finally, in the future the creation of a multiantenna ring in a circumterrestrial orbit can be considered.

Each space telescope will become a unique scientific instrument with a virtually unlimited use time. It follows from this that the development of complex rocket-space systems which is being planned today and whose mastery will require many, many years, should take into account the possibility of solving both immediate and long-range problems.

Much has already been said about the use of space technology for investigations and monitoring of terrestrial resources, in particular, for geological, hydrological and oceanological research. Interest in this direction of cosmonautics has particularly intensified during recent years. The principal direction in the development of the USSR national economy during 1976-1980 is an expansion of investigations with the use of space vehicles in study of the earth's natural resources. "Even today," stated L. I. Brezhnev, General Secretary of the Central Committee CPSU, at the Twenty-Fifth Congress, such global problems as the raw material or power bases, elimination of the most dangerous and widespread diseases and preservation of the

environment, conquest of space and use of the resources of the world ocean, are quite timely and important. In the future they will be an increasingly greater influence on the life of every people, on the entire system of international relationships. Our country, like the other countries of socialism, cannot stand to one side from solution of these problems, touching the interests of all mankind..."

In the near future it will be possible to expect the organization of a new space service -- a terrestrial natural resources service. It will be the same "standard" system as already existing services, such as space meteorology, but with broader tasks with respect to the monitoring of man's economic activity on the land and on the sea.

With each passing year there will be increasingly broader international cooperation in space. Now the main route in the development of science is through the implementation of major scientific projects which are possible only on an international basis. And whereas in the first stage international cooperation in space was limited for the most part to an exchange of the assembled results and their joint discussion, comparison of methods and in the best case, the coordination of some projects, this was followed by multilateral cooperation in carrying out terrestrial observations, accompanying space experiments. Now first place is occupied by the problem of creation of space vehicles and their use for scientific and national economic purposes through the combined efforts of different countries.

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MULTIZONAL SURVEY FROM SPACE

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[Article by L. A. Vedeshin]

Leonid Aleksandrovich Vedeshin, specialist of the "Interkosmos" Council USSR Academy of Sciences. He is concerned with matters relating to scientific-technical cooperation with the socialist and other countries in the field of study of the earth's natural resources using aerospace methods.

[Text] The "Raduga" experiment began on 15 September 1976. The "Soyuz-22" spaceship with a multizonal space camera with six objectives (the MKF-6) was launched under the program of international cooperation of the socialist countries. This camera was developed with the joint collaboration of specialists in the USSR and in the GDR. The principal purpose of the "Raduga" experiment was the testing and improvement of a new multizonal apparatus for studying the earth from space in the interests of different branches of the national economy.

A multizonal survey owes its birth to space research. In 1971, aboard the first "Salyut" orbital station, the cosmonauts V. N. Volkov and V. I. Patsayev for the first time carried out a survey using a special high-information yield, low-sensitive film, for whose processing a special technology was created. The cosmonauts tragically perished, but the survey materials, returned to the earth, were invaluable and made it possible to develop a

method for obtaining photographs of the earth from space with a very high resolution.

Then, aboard the "Soyuz-12" and "Soyuz-13" spaceships, using hand cameras, specialists tested methods for surveying individual sectors of the earth's surface in nine spectral zones falling within the limits of the visible and near-IR ranges, and also the conditions and methods for processing the collected materials. In particular, aboard the "Soyuz-12" V. G. Lazarev and O. G. Makarov in December 1973 returned to the earth about 100 photographs taken in different spectral zones. These were used in refining the relief and nature of underwater vegetation in the northeastern part of the Caspian Sea, compiling a map of soil salinity in the Mangyshlak-Buzachi region and detecting structures promising in the quest for petroleum and gas.

The multizonal surveying method was used on the "Salyut-4" orbital station. The cosmonauts P. I. Klimuk and V. I. Sevast'yanov took photographs from an altitude of 340 km with a set of four cameras in narrow spectral intervals of the optical range and in the near-IR spectral region.

Specialists of the Space Research Institute USSR Academy of Sciences over a period of years carried out development of the method for photographing the earth from space and planned the creation of a multizonal camera. In May 1973 in Moscow there was a meeting of specialists of the Space Research Institute and the People's Enterprise "Karl Zeiss Jena" for examining the problem of the possibility of joint development of a multizonal camera. During 1974 at Moscow and Jena specialists of the GDR and the USSR agreed on the principal parameters and requirements imposed on multizonal space cameras; they were to be compact, reliable, require little energy, operate well in an automatic regime. The scientific research carried out at the Space Research Institute and the many years of technical experience of the "Karl Zeiss Jena" enterprise in the field of optics and electronics made it possible to proceed at once to the development of the MKF-6, which required 2.5 years. In particular, at the Space Research Institute experts had basic recommendations on the conditions for carrying out multizonal photographing of the earth from space. The technical plan and specifications for the MKF-6 were drawn up on the orders of the Space Research Institute at the "Karl Zeiss Jena" enterprise. Its specialists worked in close contact with the specialists of the Space Research Institute, Electronics Institute German Academy of Sciences and a number of other organizations. Each design solution was discussed, modeled and analyzed. From time to time up to 600 specialists of both countries participated in the work. In a short time Soviet specialists delivered everything which is necessary to the GDR: from special materials, parts and electromechanical units to electronic components. Tests of the apparatus were also carried out jointly. Some of them were carried out at Jena using special devices created at the enterprise. Then the MKF-6 instrument underwent a long cycle of electrical, optical and mechanical tests for accelerations and vibrations on special stands in the Soviet Union. When the first MKF-6, which later flew on the "Soyuz-22," was completed, it was mounted in an AN-30 aircraft laboratory

for the purpose of checking the correctness of the methodological and technical solutions. The instrument successfully underwent these tests.

Then specialists from the GDR and their Soviet colleagues worked at Zvezdnyy with the "Soyuz-22" crew. They discussed the intricacies of operation of the apparatus and the conditions for carrying out the impending experiment. On the eve of the "Soyuz-22" launching specialists from the GDR participated in tests of the MKF-6 at the "Baykonur" cosmodrome.

The design of the "Soyuz-22" was the same as for the preceding "Soyuz" ships. The third stage of the carrier-rocket is joined to a cylindrical instrument-assembly compartment which holds the basic and reserve engines, fuel supply, and control apparatus. Situated above this is the descent module, the cabin for the cosmonauts, which holds a control panel, the ship's control levers, instruments and equipment for the main and auxiliary systems, containers for the return of exposed photographic film and scientific instrumentation. The descent module communicates through a hatch with the orbital compartment, which is intended for the carrying out of scientific experiments and for the rest of the cosmonauts. On an outer rib of this compartment, instead of the docking unit, as was the case for preceding ships, was a photo compartment, specially developed for the MKF-6. The compartment is a sealed capsule with a diameter of 1,300 mm, covered at the top by a spherical lid and on the outside having a screen-vacuum insulation. The survey was carried out through a window specially developed for this experiment, 420 mm in diameter, situated in the side surface of the cylindrical shell of the photo-compartment. On the outside the window was protected against the entrance of the sun's rays by a special tube (blind), to whose end is pressed a multiply used protective cover. Prior to the onset of photography it is opened by an electric drive. The MKF-6 is mounted within the photo compartment on four supports. The units ensuring operation of the cameras are also situated here: electronics unit and control panel. In addition, above the window there is a reserve control panel. In order to ensure the minimum falling of dust on the optical surfaces the compartment between the camera and the window is separated from the living cabins of the ship by a metal dust-impermeable partition. In the zone closed off by this partition for ensuring a stipulated heat regime there are three fans. Two of them drive air into the gap between the window and the plane of the MKF-6 objectives. A third sucks air from this cavity. In addition, still another fan is provided for ventilating the film magazines in the photo compartment. For convenience in work with the MKF-6 in the photo compartment there are two railings and a belt for the cosmonaut to secure himself.

Just what is the MKF-6 instrument? Its principal unit is the camera with six objectives, arranged in two rows symmetrically relative to the principal axis of the camera. The camera has a high resolving power, synchronized shutters and a device for compensating image displacement. The MKF-6 is a complex instrument in which mechanical, optical and electrical systems are combined.

Suffice it to mention that its weight is 160 kg and it consists of 4,000 mechanical parts, 50 printed circuits, 150 microelectronic circuits, etc. Before the first camera parts were produced, specialists studied the problem of how many spectral zones should be used and what resolution is required in a survey in the field. An answer was found after an analysis of the spectral characteristics of two thousand surface features which underwent a spectral "inventory" at the Space Research Institute. Their spectral characteristics were studied and differentiation peculiarities and conditions were ascertained.

The difference in the nature and intensity of radiation of a number of objects in the same spectral zone can be insignificant; in other zones it is manifested more strongly and makes it possible not only to differentiate these objects, but also to detect their physicochemical characteristics, which cannot be detected by eye. Yellow fields and sands or green forests of different species, surveyed in several different spectral zones on synthesized photographs, taken under color conditions, will have different hues and color intensities.

As a result of the investigations which have been made the camera designers received clear recommendations from specialists of the Space Research Institute on the necessity for having six zones. The photographs taken from orbit will be useful to specialists in different fields of the national economy.

Too high a resolution requires the creation of a complex optical system, an increase in energy consumption, and most importantly, an increase in the weight of the apparatus. On the other hand, an excess of information makes it difficult to process the frames. Therefore, in four channels of the visible spectral region specialists selected an optimum resolution of 20 m (more than 160 line pairs per millimeter in the middle of a frame), and in the two infrared regions -- 80-100 m (60 line pairs per millimeter). This is two or three times greater than the capabilities of good modern aerial cameras. The resolution in the IR channels is half as great since it is limited by the resolution of the film intended for work in the IR range. At the same time, the value of these channels is obvious: they make it possible to obtain information which is not perceptible to a viewer. This considerably broadens experimental possibilities and increases the information content of the photographs taken from space.

An equally complex problem is the choice of the width of the working band of each spectral zone and their positioning in the entire range. As a result of the investigations it was possible to select a working range of wavelengths for the MKF-6 of 480-840 nm with a band width of 40-100 nm (in each of the six parts of the spectrum), which is dependent on the selected light filters. In addition, for compensating shift the camera is supplied with an automatic system, which at the time of the surveys makes a correction for taking into account the flight velocity of the spaceship. During

the time of one exposure the "Soyuz-22" flies hundreds of meters. Therefore, each point on the film can be transformed into a line and the entire image can be blurred. In order that this will not happen and the photograph will be clear, the camera part of the apparatus undergoes a rotational motion in such a way that the photograph depicts one and the same part of the surface. The images obtained using the MKF-6 can be regarded as central projections of the surveyed sector of the earth's surface onto the plane of the photograph. In order that there be no gaps between the sectors, the electronics block of the MKF-6 feeds a command for triggering the shutter in such a way that each successive frame covers a part of the area printed on the preceding photograph. The overlap of the frames can vary from 20 to 80%. With compensation of the image shift the angular velocity is regulated in the range 16.9-38 rad/sec, which ensures the possibility of taking photographs in the range of flight altitudes 200-400 km.

Loading of film into MKF-6 in orbital compartment of "Soyuz-22" by cosmonauts V. F. Bykovskiy and V. V. Aksenov.

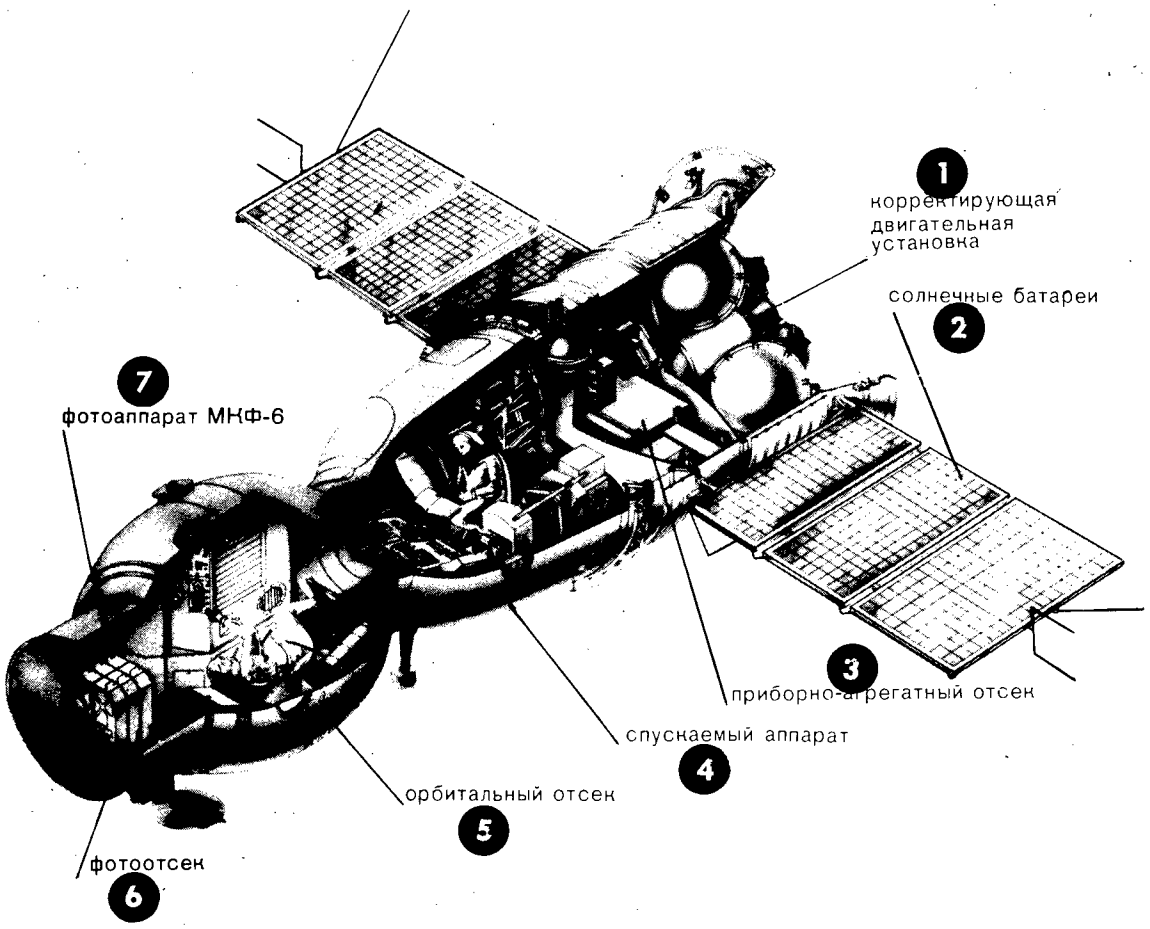


Diagram of placement of MKF-6 in "Soyuz-22" spaceship. 1) correcting engine; 2) solar cells; 3) instrument-assembly compartment; 4) descent module; 5) orbital compartment; 6) photo compartment; 7) MKF-6 camera

The resulting spectroscopic photographs make it possible to determine both the near-vertical and spatial geometrical characteristics of the photographed formations. In this case the image is constructed during very short exposures, equal to hundredths of a second.

The magazines with a weight of 13 kg each with a mechanism for moving the film are placed in the camera part, three in each row and completely interchangeable. Each magazine is loaded with 200 m of film, which corresponds to 1,000 frames. The camera makes it possible to obtain on each frame measuring 55 x 80 mm with a stipulated flight altitude of the spaceship (260 km) a strip on the earth's surface with a width of approximately 165 km and a length of 110 km. This territory is equal to 19,000 km^2.

MSP-4 multispectral projector for synthesizing photographs taken with MKF-6.

During 10 minutes of flight the MKF-6 apparatus registered about 5 million square kilometers of the earth's surface on the film. The high reliability of the apparatus, the simplicity of control and the large supply of film, making it possible with one loading of the magazine to photograph more than 20 million square kilometers of the earth's surface, make it possible to recommend the MKF-6 for carrying out both scientific and practical surveys. The entire control of the MKF-6 system is accomplished from a control panel: it is possible to set exposure, rate of compensation of image shift, degree of overlap, survey regime (single frame, reconnaissance), etc.

In accordance with the established data and system operating logic, the electronics unit produces the necessary signals for successive carrying out of all processes and operations in photographic work: reduction of the apparatus to a state of readiness for the survey, starting of the shutter motor, compensation of image shift, triggering of shutters, freeing of the film clamp, rewinding, preparation of the system for the next work cycle.

"Soyuz-22" in Flight

The first day of the flight the crew was engaged in preparations for the experiment with the MKF-6. On the fourth revolution (in the 20th and 34th seconds) the ship's engine was fired in order to enter into the working orbit (the minimum altitude was 250 km, the maximum altitude was 280 km). This almost circular orbit ensured both the required repetition of the ship's passage over the survey regions and an adequate time of its presence in orbit.

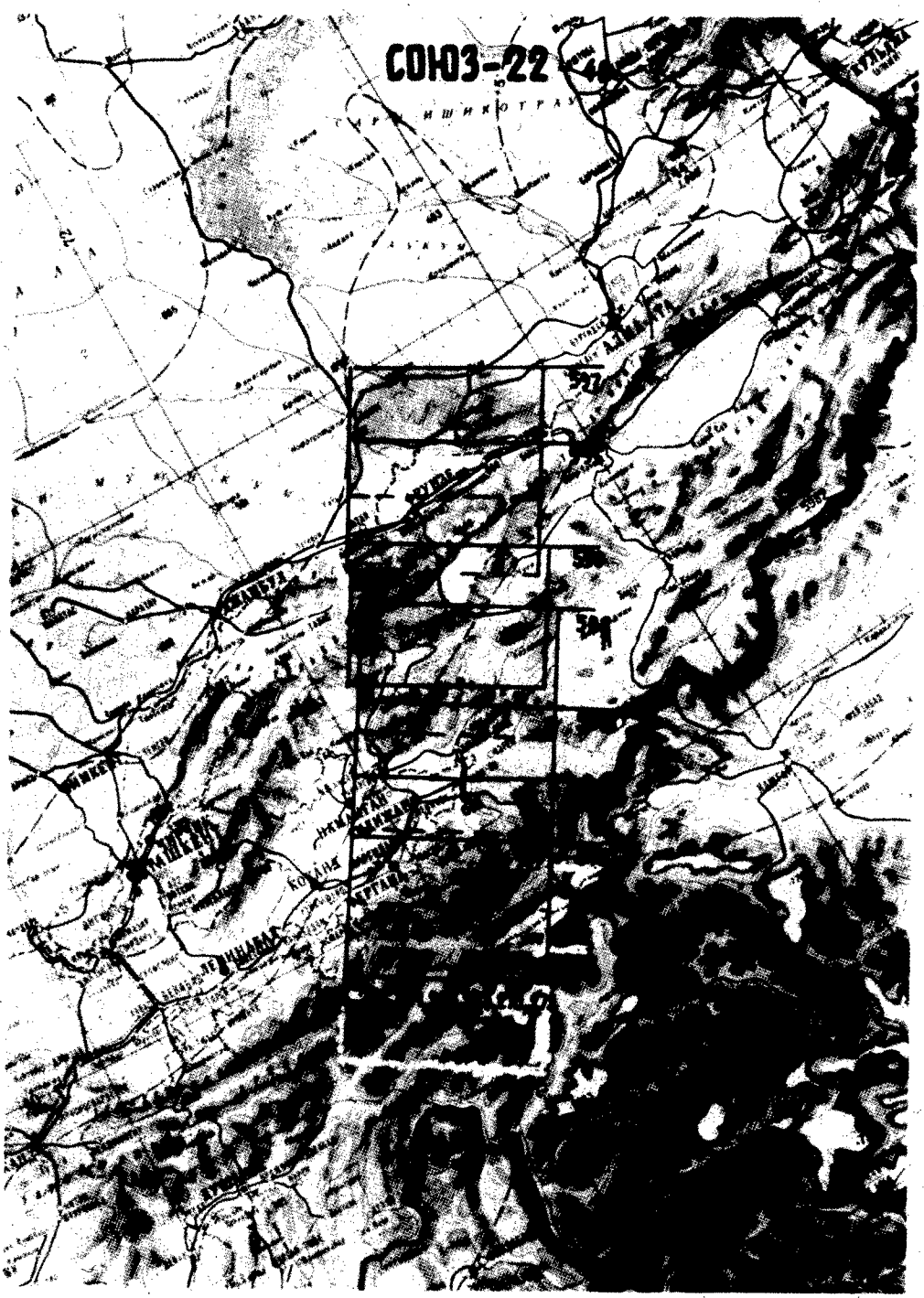
On the evening of 15 September 1976, after carrying out preparatory work, the cosmonauts proceeded to the first checking of the photographic system for functioning. All the parameters of the MKF-6 were normal. Working at the control panel in the orbital compartment, the cosmonauts opened and then closed the cover of the window and checked the process of loading of the film in the camera magazines. On the morning of 16 September V. F. Bykovskiy oriented the ship in such a way that it flew in orbit "end first" with the window "looking" at the earth. V. V. Aksenov took his working place at the control panel for the instrument. On the fifteenth revolution of the "Soyuz-22" the "Raduga" experiment began. V. V. Aksenov reported that the cloud cover was one or two tenths and that the survey was proceeding in the neighborhood of Lake Baykal and the route of the Baykal-Amur Railroad.

The orbital inclination of the "Soyuz-22" to the equatorial plane at an angle of 65° afforded an additional possibility for photographing the northern regions of the territory of the Soviet Union, GDR and Poland. The flight program of the "Soyuz-22" provided for a survey of the territory of the GDR for three days. Unfortunately, a well-developed cyclone (visibility was 6-7 units) over Central Europe on the first two days interfered with the full implementation of this plan, although the cosmonauts did work with the MKF-6 on these days. In breaks in the clouds it was possible to survey individual regions of the northwestern part of the GDR (the Rostok region, shores of the Baltic Sea) and Poland. It was not possible to survey the territory of Bulgaria, Hungary, Rumania and Czechoslovakia.

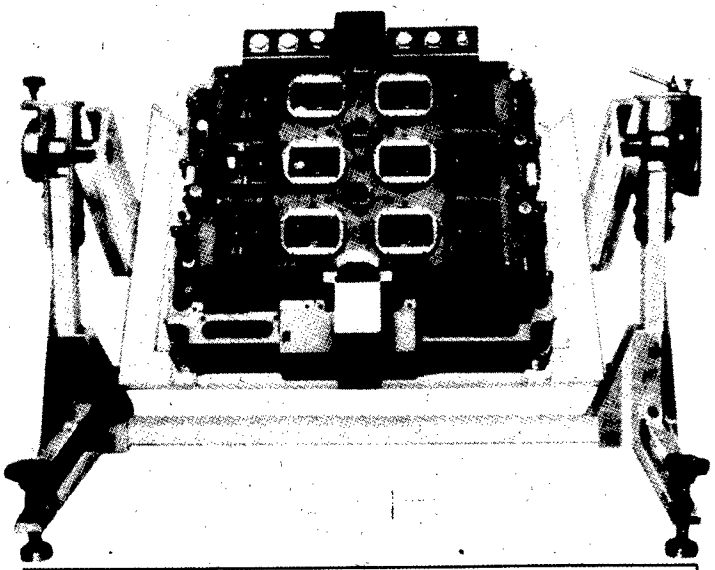
The weather over the territory of the Soviet Union favored the carrying out of a survey of most of the regions in our country: Siberia, Far East, Central Asia, Kazakhstan, Crimean Peninsula, Central Volga Region, Azerbaydzhan SSR, Southern Urals, Fergana Valley, Tadzhikistan, European USSR and individual sections of the Baykal-Amur line.

Scientific-Methodological Investigations

The space survey from the "Soyuz-22" was carried out in accordance with the requests of many scientific and industrial organizations in the country, such as the Geography Institute USSR Academy of Sciences, Geology Institute USSR Academy of Sciences, Institute of Physics of the Earth USSR Academy of


СОЮЗ-22

External view of MKF-6 flight sample



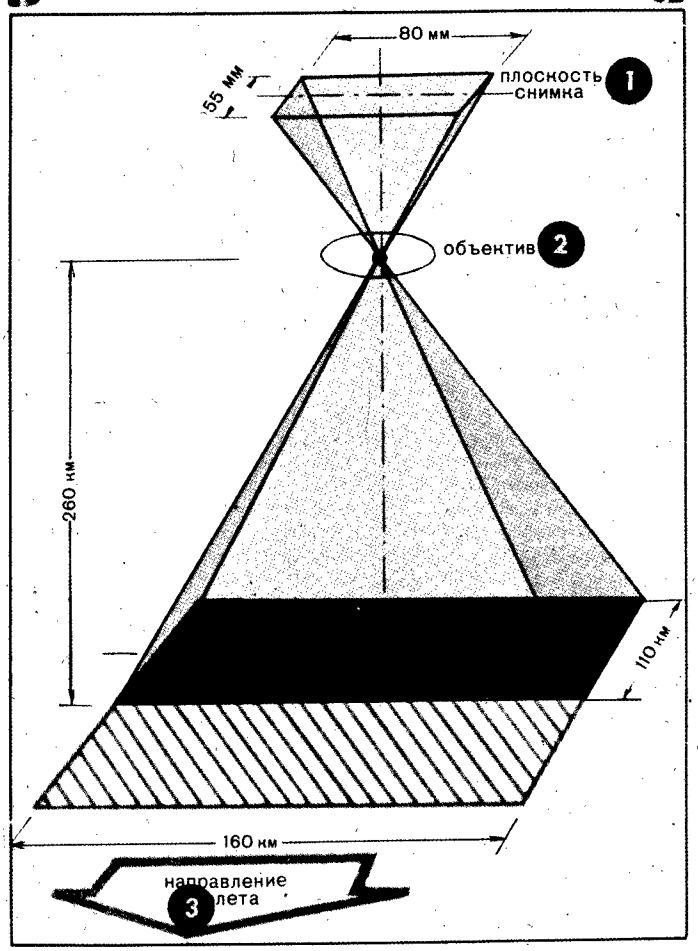


Diagram of operation of MKF-6 in flight. The MKF-6 electronics unit does not allow gaps between frames. Each successive frame takes in part of the area of the preceding frame [see accompanying map showing overlap]. 1) plane of photograph; 2) objective; 3) flight direction

Перекрывающиеся цветные снимки средней части
получены с помощью МКФ-6
корабля "Союз-22". Любое пун-
образования выделяется путем
– интенсивности

Synthesized color photographs of middle part of Vilyuy River obtained using MKF-6 from "Soyuz-22" spaceship. Any necessary natural formation is discriminated by means of a combination of light filters and the intensity of illumination of the initial photographs.

Sciences, All-Union Scientific Research Institute of Fishing and Oceanography, Scientific-Productive Combine "Lesproyekt" and many others.

The multispectral information on the earth returned from space must be interpreted, the surveyed objects must be identified and their characteristics must be determined. Using special polygons (control sectors), located in different standard natural zones and having known and permanent checkable characteristics it is possible to obtain regularly revisable standard data necessary for the reliable interpretation of aerospace photographs.

These polygons make it possible to compile a catalogue of key (typical) features and processes studied and checked by aerospace means. The catalogue includes the spectral characteristics of sectors of fields with different crops in different phases of maturity, forests of different species and age, soils of different types and moisture content, water areas, mountain regions, deserts, etc. The catalogue also includes information on the influence exerted on these characteristics by different external factors.

There are about 50 scientific polygons in our country. They constitute singular standards of vegetation of different climatic zones on Kamchatka, in Fergana, the Volga region, in Western Siberia, and elsewhere. In Siberia there is a predominance of "forest polygons." The Kursk polygon is typical for the middle Chernozem and Nonchernozem Zones of our country. The Sheki-Zakatal'skiy polygon in Azerbaydzhan is characteristic of subtropical vegetation. The Fergana polygon is characteristic for irrigated agriculture. Complex investigations are carried out in these polygons to ascertain soil temperature and moisture content, salinity, for taking photographs and spectrometric measurements of the vegetation cover with both ground spectrometers and cameras and similar instruments carried aboard helicopters and aircraft. Multisided investigations considerably facilitate the interpretation of space photographs.

It is true that the atmosphere's radiation is superposed on the results of spectrometric measurements of the earth from space. In order to exclude this and obtain keys for the interpretation of space photographs the photographing from aboard the "Soyuz-22" in individual regions was accompanied by synchronous surveys from aircraft and ground inspection of the surveyed sectors. On one of these complex expeditions, organized by the Space Research Institute, an AN-30 aircraft observatory used a "double" of the camera flying on the "Soyuz-22." Synchronously with the cosmonauts, this expedition carried out a survey first in the USSR, in the neighborhood of the Fergana valley, and then in the GDR. Parallely a group of Soviet and German specialists carried out a surface field spectrometric investigation of sectors surveyed from an aircraft. A comparison of data from these multisided investigations is of great scientific and methodological importance for interpreting space photographs.

Multizonal photographs will help in solving the problem of improving the composition of the atmosphere in large industrial centers. A special experiment on the "Soyuz-22" for photographing the moon at its rising and

setting was devoted to a study of the atmosphere. The earth's atmosphere scatters solar radiation and partially absorbs it. This introduces definite distortions into the photography and reduces image quality. In the survey the moon occupied the most different positions on the frame: at the center, along the sides; it was photographed through the earth's atmosphere and through virtually pure space. Thus, the lunar photographs were a standard for checking the adjustment of the MKF-6. These investigations are of particular interest for the Institute of Physics of the Atmosphere USSR Academy of Sciences.

A survey in different spectral zones makes it possible to obtain additional information concerning the optical properties of the atmosphere, its contamination, especially by dust particles, which are reflected in the nature of absorption and reflection of atmospheric solar radiation. A knowledge of these characteristics, in turn, is of considerable importance for an analysis and evaluation of the reliability of the results.

In addition to its scientific aspect, the "Raduga" experiment is of great national economic importance. Systems for the multisided study of natural resources and monitoring of the environment with the use of space technology are promising. Already in the present, initial phase of its development and use they introduce a weighty contribution to the study, use and preservation of nature. Most of the photographs returned to the earth will be used for practical purposes. These include the search for minerals, investigation of soils and vegetation, monitoring the use of forest resources, hydromeliorative mapping and detection of sectors of increased concentration of plankton in the seas and oceans.

Specialists in the GDR plan to solve more than a few practical problems using "Soyuz-22" photographs. In particular, they have planned a broad program for monitoring the contamination of the environment. Plans call for determining the contamination of the rivers, lakes and Baltic shore by industrial waste waters and detection of the presence of harmful impurities in the air over industrial and densely populated regions. Geologists, for example, postulate that beneath the relatively level "folds" of a number of regions in the GDR there are remnants of faults in the earth's crust, smoothed with time, where there may be still undiscovered mineral deposits. Hydrologists are interested in the depth of ground water which it would be possible to use for the needs of industry and irrigation, problems involved in the improvement of northern lands in the GDR, study of the shelf zone of the Baltic shore, etc.

Processing of Space Information

After return of the magazines to the earth the photographic films were subjected to photochemical processing in a special development apparatus. In all, in six zones of the spectrum, about 14,000 photographs of the earth were obtained. At the Space Research Institute and other organizations the collected information was processed by specialists. The film contrast

coefficient changes in dependence on the channel used. Several narrow-spectrum images are used in synthesizing black-and-white and color photographs. For this purpose the negatives are processed using a multispectral MSP-4 projector developed by specialists of the USSR and GDR and fabricated at the People's Enterprise "Karl Zeiss Jena."

The MSP-4 is a complex optical instrument making it possible to have synthesized color images with a high resolution enlarged fivefold. This is accomplished by means of a combination of light filters and the intensity of illumination of the initial photographs under both natural and color conditions, which makes it possible to discriminate any necessary natural formation. For each problem it is possible to select definite spectral zones and by means of the MSP-4 instrument the brightness of each color is selected in such a way as to discriminate the necessary objects and then to interpret them. This image can be registered on color film and color materials can be obtained for subsequent processing.

Thus, together with the testing of the means and methods for obtaining information, in the "Raduga" experiment there is solution of the problem of creating means and methods for the processing and rectification of multispectral photographs. Later plans call for using electronic computers and special ground apparatus for selecting videoinformation in the interests of the needs of different users and sorting it by regions, objects and spectral zones, for detecting and eliminating different kinds of interference arising during the survey and processing, for tie-in to a geographical coordinate system and also for image rectification into a stipulated map projection and reduction to the necessary scale, and carrying out of a definite specialized processing facilitating the interpretation and use of the collected videoinformation. Finally, the use of electronic computers will make possible a considerable acceleration of the processing of multispectral images.

The prepared maps, photographs, tables, graphs and magnetic records are evaluated on the basis of their content, scales, resolution, spectral regions of survey, color quality, coverage, aspect, admissible geometrical distortions, percentage of cloud cover, possibility of subsequent interpretation on an electronic computer. After this the materials are sent to the users. At the same time, using established forms, known in advance to all users, it is possible to create corresponding archives (catalogues, albums, microfilms, magnetic tapes, etc.), use of which can be made by all interested economic and scientific organizations.

First Results

The flight results completely confirmed the correctness of the adopted design and technical solutions. The photographs of the territory of the USSR are already being processed and sent to the USSR Geology Ministry, the USSR Ministry of Agriculture and Forestry, etc. According to the results of a preliminary evaluation, the photographs constitute material which has never been available to scientists and specialists on the national economy.

On a space photograph at a scale of 1:400,000, which covers an area of 19,000 km^2, equal to the territory of a small country, it is possible to see the Central Yakutian Plain and the middle course of the Vilyuy River. From the photograph it is possible to determine shore growths of alder (brown color) and drifts of sand along the river shores. They indicate that by the end of summer the water level in the river drops sharply, forming sandy shoals. The photograph shows the light-colored bed of the Chabydy, which at this time is completely dessicated. Amidst the Yakutian steppes it is possible to see a great many thermokarst depressions with warm water amidst the permafrost. They are surrounded by scrub and meadow vegetation. Some of these regions are beginning to be used for agriculture. On the slopes of the Central Siberian Plateau is the green sea of the taiga with larch forests, undergoing transition into steppe sectors. The photograph shows two systems of lines directed at right angles to one another. They do not reflect the structure of the surface layers, but the structure of the crystalline basement hidden deep below them.

The successful implementation of the "Raduga" experiment on the "Soyuz-22" represents an important contribution to the carrying out of the plans of the work group of the socialist countries for study of the earth from space using aerospace methods. This experiment is opening up cooperation of the fraternal countries in a new field of research important for the national economy. Space photographs taken with the MKF-6 aboard spaceships will become the property of scientists of the socialist countries, participants in the "Interkosmos" program, and will be used extensively in the national economy of these countries.

5303
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GEOPHYSICS, ASTRONOMY AND SPACE

USE OF LASER-DRIVEN ENGINES FOR SPACE LAUNCHINGS FORESEEN

Moscow NEDELYA in Russian No 44, 31 Oct - 6 Nov 77 p 21

[Article by I. Zorich: "Into Space on the Sharp Point of a Beam"]

[Text] The space age is now two decades old. We have seen dozens of launches toward the stars, and it seems that we should be used to them, but each one fills us as before with a feeling of triumph and amazement.

But scientists and designers, it seems, would prefer to have less of a spectacle in return for more efficiency. Is this monstrous booster rocket dozens of meters long really necessary? After all, the spacecraft itself, which the rocket will put in orbit, is much more modest in size and weight. The compartment in which two or three cosmonauts work and live is filled with apparatus, and although living conditions there are quite acceptable, still the cosmonauts are not permitted anything beyond what is absolutely essential, nor even a centimeter of extra living space. The more fuel is expended, the more fuel is required to lift the fuel itself, and the more cumbersome the tanks become. Incidentally, it is not only rockets which suffer to some extent or another from this deficiency, but nearly all forms of locomotion--in the air, on land, and in the water. The one exception is transportation using an electric drive: streetcars, trolleys, and electric trains. But they are tied to their cables. Naturally, cables cannot be laid in space, but are there not other means of transmitting energy without cables? And the first thing that comes to mind is, of course, the laser. A laser beam is a powerful flux of electromagnetic energy concentrated into a narrow ray, and energy is what is needed by the rocket engine to generate the reactive thrust which in turn produces motion.

About 15 years ago, the Soviet physicists G. Askar'yan and E. Moroz first turned their attention to the following fact. If a solid body (we will call it the target) is struck by a laser beam sufficiently powerful that the target does not melt, but immediately begins to vaporize, then the vapor will escape with tremendous speed, and the target will

receive a kick much like the kick experienced by the shoulder when a rifle is fired. Several years later, the noted American scientist A. Kantrowitz proposed that this phenomenon be used to drive a rocket and put a satellite into earth orbit. Although Kantrowitz's idea was purely speculative, without rigorous calculations or experimental data, it immediately attracted attention. The opinions expressed, of course, were thoroughly conflicting, ranging from fiery enthusiasm ("the future of rocket technology!") to icy scepticism ("utopian, a fantasy!"). However, certain groups of physicists and gas dynamicists both in this country and abroad decided to study the problem thoroughly and without bias in all its aspects to learn the extent of its feasibility. In the Soviet Union, theoretical and experimental investigations were headed, in particular, by Academician A. Prokhorov and by corresponding member of the USSR Academy of Sciences F. Bunkin.

How is reactive thrust produced by laser radiation?

This is what happens: if the intensity of the radiation exceeds a certain threshold (about one hundred kilowatts per square centimeter) and if the target is sufficiently massive so that the beam does not burn through it, it is immediately heated to a high temperature (about 4,000 degrees) and begins to vaporize. The rapid formation of a large mass of vapor sharply increases its pressure; a pressure difference of hundreds of atmospheres is produced between this region and the surrounding medium, and, if this takes place in a nozzle, a stream of vapor escapes to the outside with spersonic speed. The reverse, so-called reactive force presses against the opposite wall of the nozzle, which is also the base of the rocket, and the desired thrust is produced. The rocket shoots upward. But there is also another possibility.

In 1965 Professor Yu. Rayzer theoretically predicted an interesting phenomenon which was shortly thereafter discovered experimentally. If an extremely powerful flux of laser radiation is concentrated in a small region, then the air or other gas in the region is heated to a high temperature, its atoms are ionized (a plasma is formed), and there is a breakdown, a sort of microexplosion. As in any explosion, even a miniature one, this produces a shock wave which propagates with supersonic speed back along the laser beam. But at the same time, the inevitable kickback appears; that is, the reactive force. While the force is acting, the laser beam is not needed and may be shut off. But some time later another pulse of laser radiation is supplied, and the process is repeated. The reactive force is applied to the rocket in separate doses, in kicks, but they add up to a powerful thrust. There are huge advantages to this. First, fuel need not be carried on board; it is taken from the surrounding air (if the rocket is in the atmosphere), so that the rocket's payload is nearly its entire launch weight. Second, the laser operates in the pulsed mode, which allows its average power to be lowered. All this

makes the laser air-reaction engine (LARE) the most clearly promising laser engine model. But in this approach there are still many difficulties in design and construction alone.

But what possibilities may open up! Evaluations show that a laser engine using the vaporization principle can, in a number of important parameters, surpass by a factor of two or three the best liquid-fueled engines used for launching satellites and spacecraft. When the laser air-reaction engine is considered, its characteristics are clearly even better. Laser rockets may turn out to be especially convenient (and most importantly, inexpensive) for delivering relatively light loads to orbiting space stations.

We can imagine the following situation. There is a space station in orbit with a crew on board, and some instrument is out of order so that an assembly must be replaced immediately. A small rocket with a package is sent from earth, driven by a laser beam and equipped with a tiny electric reaction motor for further maneuvers during automatic approach and docking with the space station. This is clearly simpler and less expensive than sending a powerful rocket using chemical fuel.

By the way, laser-driven packages can be delivered not only in space, but to any point on earth, and in just minutes! Laser devices at fixed sites may turn out to be quite useful in launching meteorological rockets, which are usually launched vertically upward at regular intervals from a single site to altitudes easily accessible to the laser beam. Moreover, the speed of these rockets, which are not intended for putting satellites in orbit, need not reach orbital velocity.

In the future (it is still too early to say whether the near or distant future), high-capacity manned stations will be built in near-earth orbit, and these will be more than stations--rather, complete housing and production complexes with electrical power grids and industrial enterprises. Both for the construction and for the further operation of these complexes, there will be a need for the regular supply of construction materials, raw materials and various equipment to them. Evidently, much of this can be sent from the moon, and it is there that laser rockets will prove most useful. It will be possible to install laser devices which would receive their energy from solar power stations; principally, at fixed sites on the moon there is no atmosphere on the moon, so the laser beam would not be "washed out," and could drive rockets at great distances. Regular service will begin on the route from the moon to the orbital station and back.

A fantasy" Not at all. Scientists are seriously thinking over and making calculations for this alternative. Of course, much time will pass and

much effort will be required on the part of scientists and engineers before the first rocket is launched into space on the sharp point of a laser beam, but there can be no doubt that this will take place sooner or later.

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USE OF SATELLITES FOR NAVIGATIONAL PURPOSES

Moscow VODNYY TRANSPORT in Russian 28 Jun 77 p 4

[Article by V. Kalganov: "Space Bridges Over the Oceans"]

[Text] Thousands of vessels flying the flag of the Soviet Union sail the expanses of the seas and oceans. Every day any of them, wherever it may be located, near the shores of Canada or in the central part of the Indian Ocean, may send and receive radiograms and exchange information with the homeland.

At the radio centers of the Ministries of the Merchant Marine and Fishing radiomen 24 hours a day remain on watch and maintain communication with ships located at different points in the world ocean. In the USSR Hydrometeorological Center there is a special laboratory for the servicing of navigation, whose purpose is ensuring the safety of ships. Upon receiving a storm warning, the duty officer immediately advises the captains of ships located in the zone of influence of a cyclone about the advancing threat.

At the present time communication with ships at sea is maintained for the most part in the short-wave range; this is extremely overloaded and subject to natural interference. In particular, 93% of the ship-to-shore communication is ensured in a radiotelegraphic regime by the Morse code at the high and intermediate frequencies and only 7% is in a radiotelephonic regime.

This communication is extremely unreliable. The delays frequently attain six hours or more due to the unfavorable conditions for the propagation of signals and a number of other factors. As a result, daily radio exchange between the ship and shore does not exceed several dozen words. The natural question arises: what is the reason for the unstable communication?

The fact is that the short radio waves emitted through surface transmitters with a great power are refracted in the ionosphere, are deflected from their initial linear path, are curved and return to the earth. By means of multiple reflections they can travel around the earth several times. In many

cases the radio waves miss the antennas of the necessary ship if it is in a so-called "dead zone." In addition, in the ionosphere communication is frequently disrupted by storms on the sun and other interference.

One of the most important practical problems in cosmonautics is the creation of artificial earth satellites for solution of such an imperative national economic problem as the organization of a permanent and faultless system of communication and navigation at sea.

It is well known that during the time of manned space flights in different regions of the world ocean a space watch is kept by the scientific research fleet of the USSR Academy of Sciences. They ensure communication between the Flight Control Center and the cosmonauts when a "Soyuz" ship or a "Salyut" orbital station flies over opposite hemispheres of our planet. The sea "scanners of space" listen for the signals arriving from the abyssal depths of the sky and through their antennas send them to the "Molniya" communications satellite, from whence they are again transmitted to the earth.

The ship - satellite - ground station radio bridge eliminates frequent disruptions of radio communication. It faultlessly and rapidly connects subscribers.

The All-Union Combine "Morsvyaz'sputnik" was organized in the USSR Merchant Marine Ministry in 1976. It ensures the technical operations of satellite communications and navigational facilities on the seas to the north and south of the equator.

The purpose of a satellite communication system is ensuring stable, effective and around-the-clock communication between ships located in different regions of the world ocean and their home ports. The space radio bridge operates in such a system. The parabolic dish of the transmitter antenna on the ship sends a signal to the relay satellite. Passing through a complex system, the signal, amplified and converted, is fed to a transmitter, and from there to the transmitting antenna of the satellite. It is received by ground stations having an output to a telephonic communication system. The radiotelephonic connection is made virtually instantaneously.

The on-board relay apparatus of the satellite will operate in the centimeter range. These waves have interesting and important properties. Such waves do not bend around the earth's surface, but are propagated linearly. Their distinguishing characteristic is that they pass freely through the ionosphere and pass into interplanetary space. They differ advantageously also in such a remarkable property as almost complete noise immunity.

However, the solution of the problem of satellite communication over the area of the seas and oceans even in such large countries as the USSR and the United States. It must be solved on a global scale. Therefore, in September of last year 47 countries decided to combine their efforts and

resources for establishing an international satellite communication system for servicing ships in the merchant marine. The decision to participate in the international organization Inmorsat was also made by other socialist countries -- East Germany, Poland, Bulgaria and Cuba.

Satellites of the Inmorsat system will be put into geostationary orbits: one over the Atlantic Ocean, a second over the Pacific Ocean, and a third over the Indian Ocean. And an artificial satellite in a geostationary orbit has a remarkable property: for the terrestrial observer the impression is created that it hovers motionless in the abyss of space above a definite region of our planet. This is attributable to the fact that the angular velocities of rotation of the earth and satellite coincide. The apparent period of revolution of such a satellite is equal to infinity. In actuality, the velocity of the satellite, remaining constant during its motion in orbit, is 3.1 km/sec and the period of revolution is equal to 24 hours. A geostationary orbit can lie only in the equatorial plane at an altitude of 36,000 km above the earth's surface.

A satellite system for the servicing of the merchant marine not only to a considerable degree improves communication with ships, but also serves navigational purposes; it facilitates rescue operations at sea. In particular, a satellite ensures communication between ships and ground stations via 30-40 radiotelephonic channels. And each of these channels is the equivalent of 20,000-25,000 telegraphic radio channels. One must agree that the advantages are many. In short, a satellite communication system performs a good service for seamen. It will ensure a time of delivery of a communication from the land to the vessel at sea in the course of a few minutes. It can be used extensively by members of the crew and their families.

The ship - space - ship radio bridge will operate continuously. As a result of this the control of ship movement will become more routine. The possibility is appearing for the simultaneous communication servicing of a considerable number of ships. A satellite system will give great advantages to navigation. Satellites will become space radio beacons.

According to computations of specialists, by the year 1980 the number of vessels with a large tonnage (more than 10,000 tons) will attain approximately 14,000.

The collision of vessels is a common phenomenon. They are particularly common at the approach to ports, in narrow straits and channels. Statistics show that the collision of ships and running aground occurs on an average of 15 times a day. A satellite system will make possible a considerable reduction of such accidents. According to predictions, in the next 20 years for vessels located in the open sea it will be adequate to determine their position each two hours with an accuracy up to 3.5 km and in restricted water areas with a high traffic it is necessary to determine constantly the corresponding position with an accuracy to 0.5 kilometer.

All the navigational systems, other than satellite systems, have limitations which hinder their universal use. Navigational systems using satellites in geostationary orbits are capable of ensuring the required accuracy in restricted water areas because a satellite navigation system reduces errors in position determination to negligible values.

A space navigation system will also be of inestimable value to fishing ships. In those cases when a rich catch is taken and the vessel must return to this same region satellites will again be of assistance to it.

And in conclusion -- about icebergs. These messengers from the Arctic and Antarctica wander for years over ocean areas, creating a threat to navigators. Now in most cases it is possible to detect them only when they are in the paths of ships. And by no means always do captains learn in time about the threatening danger. But from space there is no difficulty in discovering these giant ice blocks and tracking their movement.

Although the Inmorsat organization plans to create the first operational satellites within several years, even now in our country on large ships under construction provision is made for the installation of equipment for satellite communication. According to the calculations of specialists, the expenditures on satellites and the ground complex of the satellite system for the servicing of ships will pay for itself in seven years and the cost of space communication equipment for each vessel will pay for itself in one year.

As a result of the efforts of scientists, designers and engineers, a new branch of cosmonautics is being born: a satellite communication system for the servicing of ships in the merchant marine and in the fishing fleet. Space is opening a new chapter in oceanology and fishing.

5303
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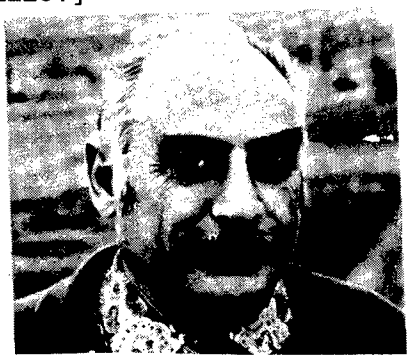
MULTISPECTRAL AEROSPACE METHODS FOR STUDY OF EARTH RESOURCES

Moscow PRIRODA in Russian No 10, Oct 77 pp 10-23

[Article by Yu. M. Benilov]



Yuriy Mikhaylovich Benilov, Candidate of Technical Sciences, Docent, Senior Scientific Specialist at the Space Research Institute USSR Academy of Sciences. He is concerned with matters relating to the study of natural resources from space.

[Text] The recent decades of economic development of different countries, especially the industrial countries, have been characterized by the ever-increasing use of the earth's natural resources and an ever-increasing impact on nature.

The traditional methods for investigating the earth's resources for the most part used information which was obtained in the course of land and sea expeditions and aerial surveys. However, these methods for obtaining information have a number of significant shortcomings which reduce the effectiveness of investigations of the earth's resources and monitoring the effect on nature. These include very great expenditures of time on the collection of information, the high cost of collecting information in inaccessible regions, the small area of simultaneous coverage, the great expenditures of time on transmitting the results of measurements from the

places where they were carried out to the places of analysis and interpretation, the great expenditure of work and technical resources.

All this forced the initiation of work in the USSR, United States, France, Great Britain and a number of other countries for finding new methods for obtaining information on the earth's resources.

Successes in the development of space technology and methods for the exploration of space both in the field of equipment and in the field of its practical use are making it possible to create space systems which to a considerable degree are free of the mentioned shortcomings. The principal peculiarities of these systems include the possibility of obtaining information of a global and regional character with relatively small expenditures of time in an adequately great simultaneous scan of the earth's surface with line resolutions in the range 10-100 m (in the scanning band 100-200 km) to 0.25-2.5 km (in the scanning band 500-1,000 km or more), the possibilities of transmitting the results of observations from the place where they are carried out (space vehicle) to the place of their analysis and interpretation almost on a real time scale (with a relatively small lag). The time of active existence of an information space system can attain 3-5 years or more.

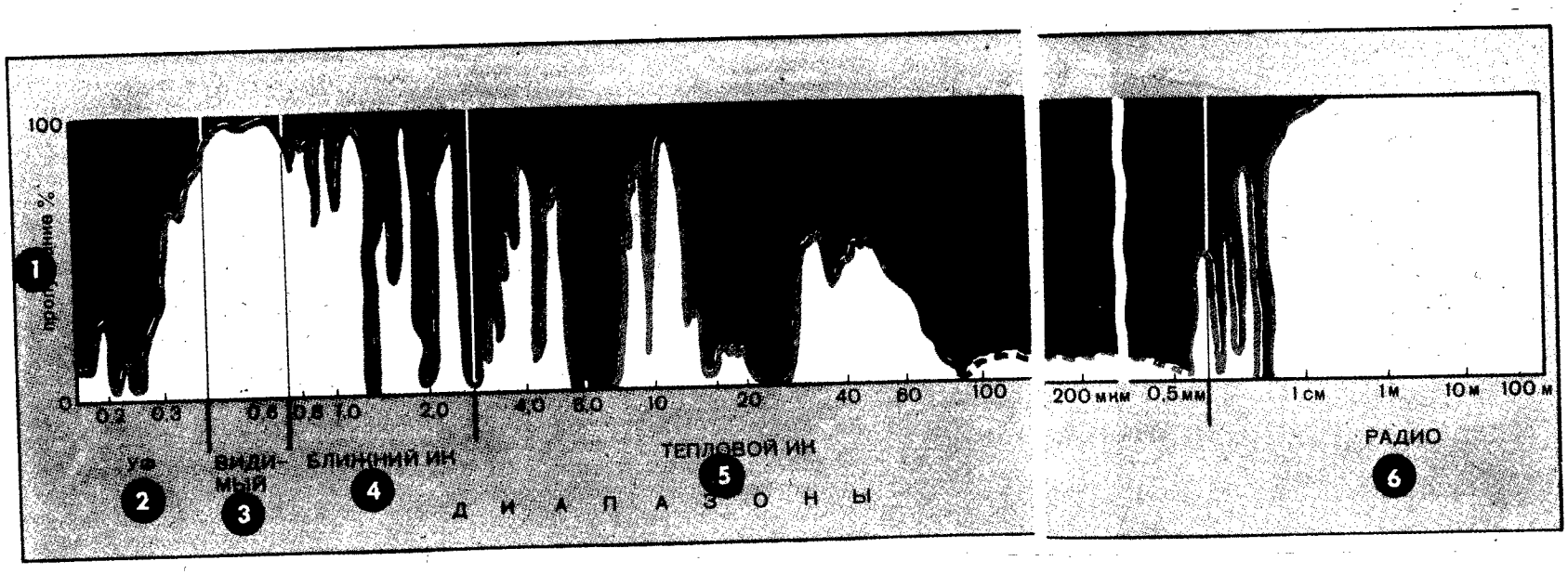
These peculiarities make it possible, using space information systems, to detect global and regional patterns which cannot be determined on the basis of use of ground and aerial methods.

Principal Carriers of Information on Terrestrial Resources

It is well known that in circumterrestrial space it is possible to register electromagnetic radiation in a very broad range of wavelengths, fluxes of different particles, magnetic and gravitational fields. The electromagnetic radiation emanating from the earth, the characteristic magnetic and gravitational fields are related directly to the earth. However, modern measurement instruments ensure the highest information yield in cases when the electromagnetic information emanating from the earth is used as the carrier of information.

The electromagnetic radiation emanating from the earth includes the solar radiation reflected from it and from the atmosphere and the characteristic radiation of elements of its surface and atmosphere.

In space (on a space vehicle) it is possible to register only that part of the radiation escaping directly from the earth which can pass through its atmosphere without significant absorption. It follows from an examination of the dependence of the coefficient of transparency of the earth's atmosphere on wavelength of transmitted radiation that in space it is possible to register the electromagnetic radiation of the earth's surface without significant absorption by the atmosphere in the wavelength ranges: from 0.375 to 2.5 μm (visible and near-IR range), from 3 to 6μm (intermediate



Dependence of coefficient of atmospheric transparency (in %) on wavelength of transmitted electromagnetic radiation. 1) transmission; 2) ultraviolet; 3) visible; 4) near-infrared; 5) thermal IR; 6) radio (range)

IR range), from 8 to 13μm (thermal IR radiation), from 0.5 cm to 4 m (microwave radioemission).

Thus, as the principal carriers of information on the earth's resources and the phenomena transpiring at its surface it is possible to use the electromagnetic radiation emanating from the earth in the indicated regions ("transparency windows") of wavelengths.

The earth's surface and the objects situated on it reflect incident solar radiation but the degree of reflection is dependent on the nature of the object, color and state of its surface. An examination of the reflectivity of some terrestrial objects shows that as criteria for the interpretation of space information, in addition to the criteria traditionally used in the processing of aerial materials, it is possible to employ the spectral differences in reflectivity of some objects from others. These differences are almost unambiguously reproduced in the spectral characteristics of reflected solar radiation, which can be registered on a space vehicle in the form of images of the subsatellite surface of the earth in analog and digital form in different parts of the spectrum. An analysis of these images and comparison of the images of one and the same sector of the earth's surface in different spectral zones makes it possible to identify surface formations (phenomena) and to determine their state.

It is known that any body whose temperature differs from absolute zero (-273°C) emits electromagnetic energy. The intensity, and to a certain degree, the spectral composition of this radiation (energy distribution by wavelengths) are determined by the absolute temperature, the physicochemical properties of the body and the nature of its emitting surface. With a temperature usual for the earth's surface and natural objects (from -50 to +50°C) sufficiently strong (for registry on a space vehicle) radiation occurs at wavelengths greater than 6-7μm, including in the microwave range. Anthropogenic and natural objects (cities, many industrial objects, geothermal sectors of the earth's surface) having a temperature contrast relative to the background (adjacent surface of the earth) of about 5-10°C or more and a characteristic temperature more than +50°C can create electromagnetic radiation of sufficient intensity at wavelengths 3-6μm.

The examined information carriers are natural. However, in these same parts of the spectrum of electromagnetic waves it is possible to use artificial emitters mounted on space vehicles and register there the radiation reflected from the earth and surface objects (formations). It is possible to register these reflected radiations in precisely the same way as in the considered cases.

As already mentioned, it is feasible to use electromagnetic radiation as a carrier of information on the earth's resources only in the "transparency windows" of the atmosphere. However, the atmosphere itself reflects solar radiation and thus is a source of radiothermal electromagnetic energy. This radiation, on the one hand, carries information on the atmosphere and is used in existing space meteorological systems ("Meteor"

λ-400 мкм

λ-650 мкм

λ-500 мкм

λ-840 мкм

Space image of agricultural lands. [MKM = μm]

system in the USSR); on the other hand, it masks the radiation escaping directly from the earth's surface. Therefore, when carrying out surveys (measurements) from space vehicles the conditions are selected in such a way that the interfering effect of the atmosphere will be minimum. Such conditions are usually satisfied during the light time of day when the solar angle relative to the horizon is more than 15-20°, when there is a sufficiently transparent atmosphere and a small amount of cloud cover (the relative area of the earth's surface covered by clouds within the limits of the scanning zone must not exceed 15-20%).

Some Problems in Investigating Terrestrial Resources Using Space Information

The problems involved in investigating the earth's resources and monitoring the environment include an extremely great number of the most varied subjects, taking in different fields of knowledge. A great many of them can be solved quite effectively on the basis of use of space information. As an illustration, we will mention some of them.

In the field of geology, on the basis of global and regional patterns and analogies, which can be detected only on the basis of space information, it is possible to predict regions which are promising in the quest for petroleum, gas, different ores and coal.

This same information is used in the preparation of geological and geothermal maps, routine and constant observations of seismically active zones on the earth, geological support of major industrial construction (such as the Baykal-Amur Railroad, large hydroelectric projects and industrial complexes of the Sayan-Shushenskiy type) and a number of other geological problems. It should be noted that the use of space information in some cases can considerably reduce the material expenditures and the time required for solving a number of problems which cannot be solved at all without the use of such information.

In the field of hydrology, on the basis of an analysis of space multispectral images of the earth's surface it has been possible to detect new open sources of fresh water and it is possible to predict sectors promising for the quest for ground water in desert and steppe regions; it is possible to carry out routine monitoring and prediction of high water, inundations, regions of flooding, runoff of water after high waters and inundations, and also routine monitoring of the effectiveness of rescue measures and hydrological monitoring of changes in the regime of rivers feeding major hydroelectric complexes and the like (hydroelectric power stations, irrigation systems, etc.).

In the field of oceanology, oceanography and navigation the use of space information ensures solution of a number of applied problems such as the warning of and observation of severe phenomena exerting an influence on the effectiveness and safety of marine navigation and constituting a danger for coastal regions (tsunamis, hurricanes, storms), continuous hydrographic

monitoring of sea routes, monitoring of ice conditions and routine prediction of sea navigation in the high latitudes, monitoring of the movement of large ice formations (ice fields, icebergs) into the middle and low latitudes and support of the corresponding services providing warning services.

In the field of sea and ocean fishing the analysis of space multispectral information makes it possible to detect sectors of the seas and oceans rich in phytoplankton and ensure constant observations of its migration and carry out continuous observations of the distributions of water temperature over the surface of the seas and oceans.

In turn, the enumerated data make it possible to solve such practical problems as detection of the migration routes of species of fish and marine animals, predict regions promising for commercial sea and ocean fishing, and to draw up instructions for fishing fleets.

In the field of monitoring the state of the sphere of human habitation the use of space multispectral information makes it possible to carry out constant observations of the degree of contamination of rivers and lakes by waste water and industrial waste, contamination of air by industrial enterprises and transport, effectiveness of purification structures and a complex of measures preventing the contamination of water and air, influence of anthropogenic factors (development of cities, communication networks, industrial construction) on nature.

In the field of agriculture an analysis of space multispectral information makes it possible to monitor the real distribution of agricultural crops over quite extensive regions, determine the degree of readiness of soils and agricultural crops for carrying out corresponding work (plowing, sowing, harvesting, irrigation, fertilizing) and for carrying out a routine evaluation of the quality of carrying out this work. In addition, the use of space information can substantially facilitate the detection of sectors contaminated by predators and diseases, ensure monitoring of their propagation and the effectiveness of routine measures for contending with them, and also facilitating clarification of the degree and dynamics of microbial population of the soils, improvement in soil maps for large regions and land use maps.

In the field of forestry the use of space multispectral information can increase the reliability of evaluations of the commercial reserves of timber and their distribution over large (especially inaccessible) regions, the effectiveness of the planning of industrial use of commercial types of timber and the restoration of forests (cutting and replanting), ensure the routine monitoring of the condition of large forest areas, define sectors of the forest contaminated by predators and diseases and ensure the effectiveness of measures for contending with them and also detect the primary centers of forest fires and ensure monitoring of their propagation and the effectiveness of antifire measures over great regions (which is particularly

important for inaccessible regions).

An examination of the problems involved in investigations of the earth's resources and monitoring of the state of the environment shows that they all can be classified on the basis of requirements on the schedule for the revision of information and on the degree of its spatial detail.

On the basis of requirements on the routineness of data revision, all the problems can be divided into the following groups. Problems of an emergency warning character (forest fires, tsunamis, hurricanes, floods, etc.) requiring continuous revision of information (virtually at a real time scale). Problems requiring revision of information with a periodicity from a day to a week (a number of problems in agriculture, hydrology, oceanology, forestry, environmental monitoring). Problems requiring revision of information with a periodicity from a week to a month (some problems in agriculture and forestry, oceanology and hydrology, sea and ocean fishing). Problems requiring revision of information with a periodicity from one month to three-four months (some of the problems in agriculture and forestry, monitoring of the environment, oceanology and oceanography, navigation, geology and land improvement). Problems requiring revision of information with a periodicity from three-four months to a year or more (a number of soils problems, problems in geology, oceanology and oceanography, forestry).

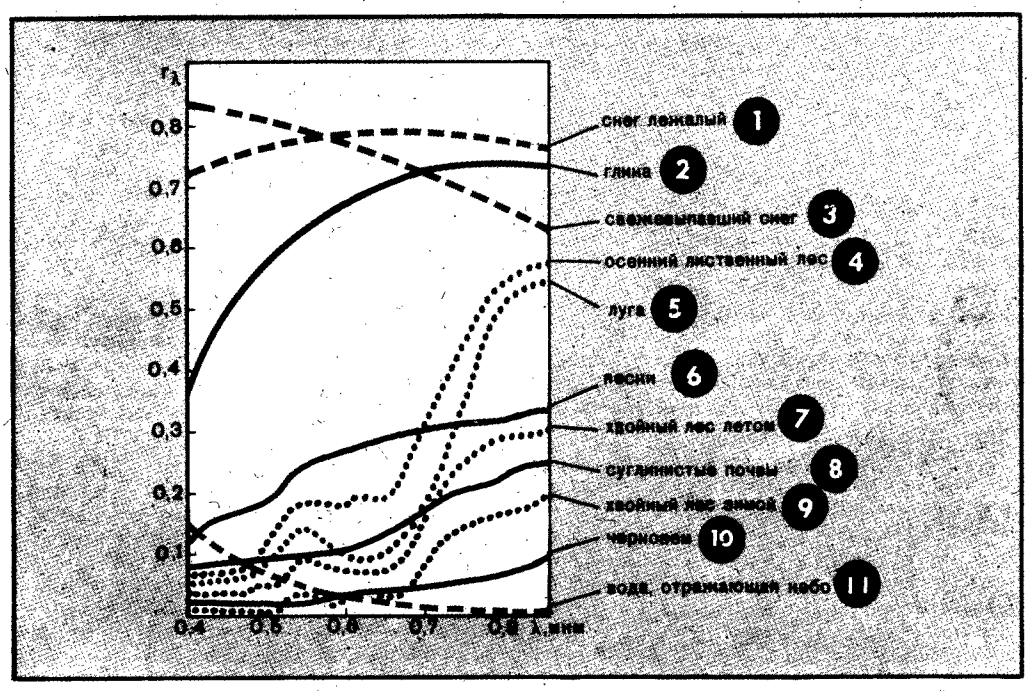
On the basis of requirements on the degree of spatial detail of information to be used in investigations of the earth's resources and monitoring of the environment it is possible to define problems whose solution requires only linear resolutions of 0.5-1 km or more (the problems for the most part included in the first group), problems which require linear resolutions of 100-200 m (for the most part those entering into the second, third, fourth and in part the fifth groups) and linear resolutions of 30-50 m (for the most part problems in the fifth and in part the fourth groups).

An examination of the problems in investigations of the earth's resources requiring the revision of information from a real time scale up to a month also shows that these are large-scale problems, that is, the range of users participating in their solution (interpretation and analysis) is broad and varied. The relatively rapid aging of the information necessary for their solution requires a sufficiently routine interpretative processing. The use of traditional visual-instrumental interpretation methods employed in an analysis of the results of an aerial photographic survey cannot ensure the necessary routineness even with a substantial increase in simultaneously participating interpreters because the rate of formation and the volumes of space information will be very great. For example, if a simultaneous observation, reduced to the earth's surface, measuring 200 x 200 km, with a linear resolution of about 100 m is used as one conventional frame, with four spectral channels for obtaining the images the rate of formation of the information will be greater than $5 \cdot 10^6$ binary digits/sec, and the total volume will be greater than $1 \cdot 10^8$ binary digits. With an improvement

in linear resolution by a factor of 2 (50 m) this rate and volume will increase by a factor of four ($2 \cdot 10^7$ binary digits/sec and $4 \cdot 10^8$ binary digits).

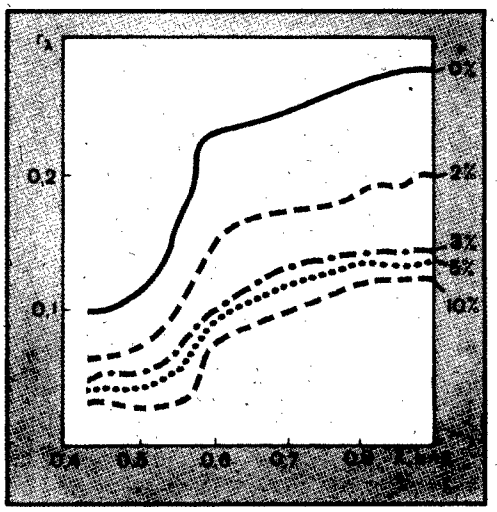
These circumstances require the use of computer analysis and interpretation method, which in turn leads to the need for the representation of space information not only in the form of images, but also the obtaining of quantitative data on the intensity of the registered fluxes of electromagnetic energy.

These classifications are to a certain degree arbitrary, but they make possible a more graphic matching of the possibility of space technology, different means for the formation and transmission of information from a space vehicle to the place of analysis and interpretation with the tasks of investigating the earth's natural resources and monitoring the environment.



1) Lying snow
2) Clay
3) Freshly fallen snow
4) Autumn hardwood forest
5) Meadow
6) Sands
7) Summer coniferous forest
8) Clayey loam soils
9) Winter coniferous forest
10) Chernozem
11) Water reflecting the sky

[Along x-axis: μm]



At top: dependence of reflective properties of quartz sand with different moisture content (in relative units) on wavelength of incident sunlight. At right: dependence of reflective properties of different surface features (r_λ) [in relative units] on wavelength of incident sunlight.

Technical Means for Producing Information

It has been shown that the principal carriers of information concerning the earth's resources are electromagnetic radiations: reflected solar, characteristic radiothermal and reflected artificial. The registry of these radiations is accomplished by different technical means. Electromagnetic radiations in the visible and near-IR ranges can be registered by means of photographic (λ = 0.375-0.9μm) and television (λ = 0.375-2.5μm) means.

Electromagnetic radiations in the IR radiothermal sector (λ = 3±6μm and λ = 8-13μm) can be registered by means of radiometric optical-electronic instruments. Electromagnetic radiations in the microwave radio range are registered using microwave radiometers. All the enumerated technical means are usually called "passive means."

As the artificial sources of electromagnetic radiations which after reflection from the earth's surface will be registered on a space vehicle, it is possible to use laser sources in the visible and IR ranges and radio transmitters can be used in the microwave radio range. The technical means, which include artificial sources of electromagnetic radiation, are usually called "active."

Now we will examine the basic principles for the construction of the technical means used most extensively at the present time and the peculiarities of their use in a space information system for investigating the earth's resources and monitoring the environment.

The photographic means for a multispectral survey can be either a multiobjective (multichannel) camera with the registry of all color-separated (spectrum-separated) individual images on a common light-sensitive film or a complex of cameras of the same type forming a multichannel photographic system and combined control device which ensures the simultaneous photographing of the earth's subsatellite surface.

All the channels in these systems ensure obtaining images of one and the same part of the earth's surface at the same scale and at the same time. However, in each channel these images are obtained in different parts of the spectrum of electromagnetic waves by means of use of specially selected combinations of filter-objective-film.

The images obtained using photographic means are central projections of the corresponding parts of the earth's surface.

Now we will examine the distinguishing characteristics of photographic means and methods for obtaining information.

1. After a photographic survey in space the light-sensitive materials with the registered images must undergo photochemical processing. Retention of the metricity of images requires the carrying out of photochemical processing under quite rigid standard conditions with respect to the purity of the used reagents, temperature and time of processing. These conditions can be ensured only in specialized ground laboratories.

The delivery of exposed photomaterials from a space vehicle to a ground laboratory can be ensured either with the landing of a space vehicle itself on the earth or when a special capsule is dropped from it. The first delivery method is the easier. This means that the light-sensitive materials can undergo photochemical processing only after the ending of the fixed lifetime of the space vehicle (in the case of automatic spacecraft) or after the landing of a transport ship or descent module (in the case of use of manned vehicles as carriers of survey equipment).

2. Multispectral photographic information in the form of individual color-separated images with a high degree of spatial detail can be analyzed and interpreted directly by visual-instrumental methods. In addition, from individual color-separated materials it is possible to synthesize color images in natural and conventional colors, which makes possible considerably easier analysis and interpretation and an increase in their reliability.

3. The use of quantitative (digital) methods with the use of an electronic computer in the analysis and interpretation of great flows of photographic multispectral information presents quite great technical difficulties. These difficulties are attributable to the fact that digital methods require an automatic element-by-element matching of color-separated images and an allowance for the real scatter of spectral sensitivities of photographic materials and photochemical processing regimes. As a result all

this leads to a deterioration of spatial detail and a decrease in the reliability of interpretation.

The enumerated characteristics make it possible to use photographic multispectral materials for solving nonroutine problems in investigation of the earth's resources and monitoring the environment. This necessitates information with a high degree of spatial detail. A graphic example of the modern implementation of photographic methods for obtaining multispectral information in the interests of investigations of the earth's resources is the flight of the "Soyuz-22" with a MKF-6 multizonal camera. A description of this space experiment and its first results are given in an article by L. A. Vedeshin entitled "Multizonal Survey from Space," published in the same number of this journal.

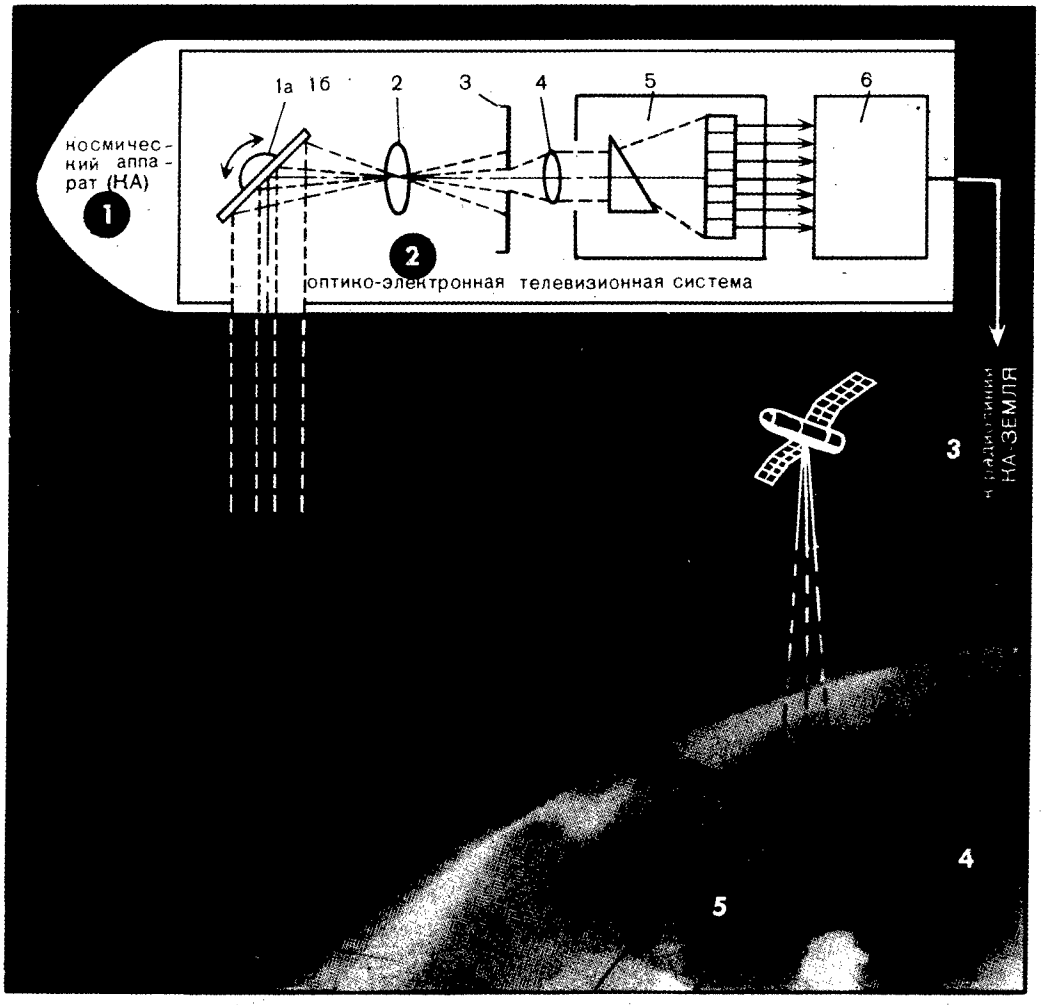
Television means for obtaining multispectral information used at the present time are optical-electronic multichannel scanning systems.

Optical-electronic multispectral television systems differ from frame systems in that in these systems the breakdown of the image into individual elements is accomplished by motion of the spacecraft carrier system relative to the earth and mechanical oscillations of a special optical device. In addition, the separation of image elements into individual spectral components is accomplished by means of a set of filter-photodetector pairs. Thus, the image for all the channels is created by a single common optical-mechanical subsystem and corresponding spectral components of one and the same image element act on their photodetectors.

The principle of operation of an optical-electronic multispectral television system is as follows.

The image of the subsatellite earth's surface, reflected by a mirror through an objective, is projected onto the diaphragm plane. The diaphragm itself is completely opaque. At its center (directly on the optical axis) there is an opening. The light of that part of the image which is incident on the opening passes beyond the diaphragm and through a collecting optical system is incident on filters with photodetectors. Each filter-photodetector pair discriminates its fraction of electromagnetic energy from the common light flux (this fraction is the energy contained in the corresponding spectral interval) and transforms it into an elementary electric signal.

The image of the subsatellite surface of the earth caused by mirror oscillation, which is accomplished by an electromechanical unit, is moved across the spacecraft flight trajectory relative to the diaphragm opening. Simultaneously due to the motion of the spacecraft this image moves relative to the opening of the diaphragm along the trajectory. Thus, the light from all image points on the earth's surface in the scanning zone successively passes through the diaphragm opening. In this process a sequence of elementary electric signals is formed at the output of each of the photodetectors and color-separated images can later be formed from these.



1) space vehicle; 2) optical-electronic television system; 3) radio link to earth; 4) direction of spacecraft motion; 5) scanning band

In this system the width of the scanning band on the earth's surface is determined by the angle of oscillation of the mirror and the focal length of the objective.

The detail of the images (resolution) is determined by the dimensions of the openings in the diaphragm; for example, for ensuring a linear resolution of 50-100 m on the earth's surface with a flight altitude of the vehicle of about 1,000 km, with a focal length of the objective of 500-1,000 mm, the dimensions of the opening should be about 25-100 m. The frequency of mirror oscillations is set in such a way that during the time of one oscillation the spacecraft will move along the trajectory relative to the earth not more than the width of one line (the linear dimensions of a line are equal to the magnitude of a resolvable element on the earth

and for the cited example the frequency of mirror oscillations should be about 160-80 oscillations per second. [The practical realization of such frequencies of mechanical oscillations involves quite great difficulties. Therefore use is made of special methods (multiline scanning) which make it possible to decrease the frequency of mirror oscillations (in the cited example, with five-line scanning) to 32-16 oscillations per second, and with ten-line scanning to 16-8 oscillations per second.]

The output signals of the photodetectors are fed into an electronic subsystem into which are also fed servicing electric data and in which the total signal of the system is shaped.

The output signal of the system is introduced into the radio channel for transmission to a ground reception station or is registered by an on-board magnetic recorder. In the case of registry of multispectral videoinformation its reproduction and transmission to the data reception point is accomplished in accordance with a special command or program transmitted from the earth.

The principal peculiarities of the multispectral videoinformation which can be obtained using optical-electronic television systems are:

1. The possibility of shaping and transmitting information to the user at a time scale close to real time (with a relatively small lag from the moment of its shaping).

2. The method of its analysis and interpretation, which can be quantitative (digital) with the use of electronic computers (a visual method with the participation of corresponding specialists is not precluded).

The multispectral videoinformation can be transmitted to earth for use in the form of data recorded on magnetic tape and in the form of color-separated images.

3. The forming of videoinformation in any part of the spectral range: 0.375-2.5; 3-6 and 7-13μm. The degree of detail can be ensured in the wavelength range

λ = 0.375-2.5μm, 50-250 m;
λ = 3-6μm, 300-600 m;
λ = 8-13μm, 800 m - 2 km.

The enumerated peculiarities make it possible to use multispectral videoinformation obtained using optical-electronic systems for solving all types of problems in investigation of the earth's resources and monitoring the environment, including emergency-warning and routine, not requiring linear resolutions less than 50-100 m with the use of electronic computers for analysis and interpretation.

In a number of cases in the wavelength range 8-18 μm use is made of nonscanning radiometers ensuring the collection of data on the intensity of radiation in the indicated wavelength range along the subsatellite path. The principle for constructing such instruments is similar to those already considered.

As carriers of optical-electronic multispectral television apparatus it is possible to use both automatic and manned space vehicles.

Microwave radiometric systems include two types of instruments. One type of instrument ensures obtaining radio images of the subsatellite surface of the earth with a quite small degree of detail (linear resolutions of about several kilometers). The second type of instrument is nonscanning microwave radiometers ensuring the collection of data on the intensity of radiations in a stipulated range of radio waves along the subsatellite path. At the present time the second type of instrument has come into the broadest use.

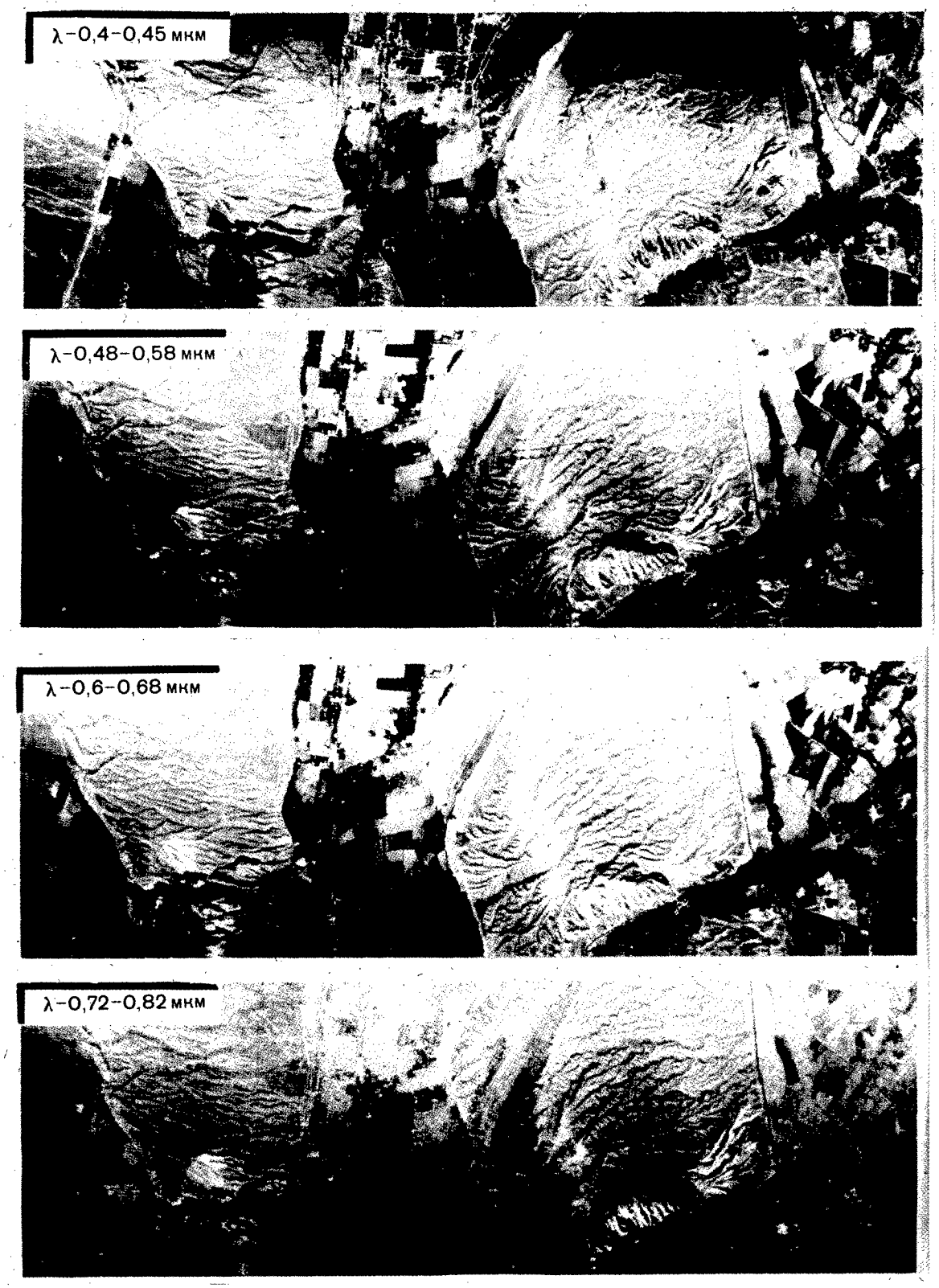
Nonscanning microwave radiometers include an on-board antenna directed toward the earth along the local vertical and a radio receiver. The output signal of the radio receiver can be introduced directly into the radio link between the spacecraft and the earth for the transmission of data to the data reception point or is registered by an on-board magnetic recorder and then in the usual order is transmitted to the data reception point.

The information received by means of microwave radiometers can be used effectively in solving a rather broad range of problems involved in investigation of the earth's resources and monitoring the environment, including routine and emergency warning, with the use of electronic computers for analysis and interpretation.

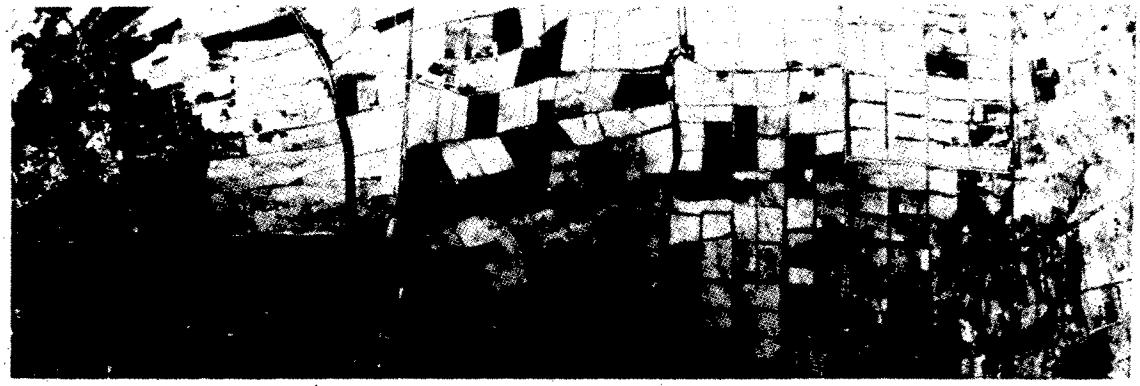
Both automatic and manned space vehicles can be used as carriers of microwave radiometric apparatus.

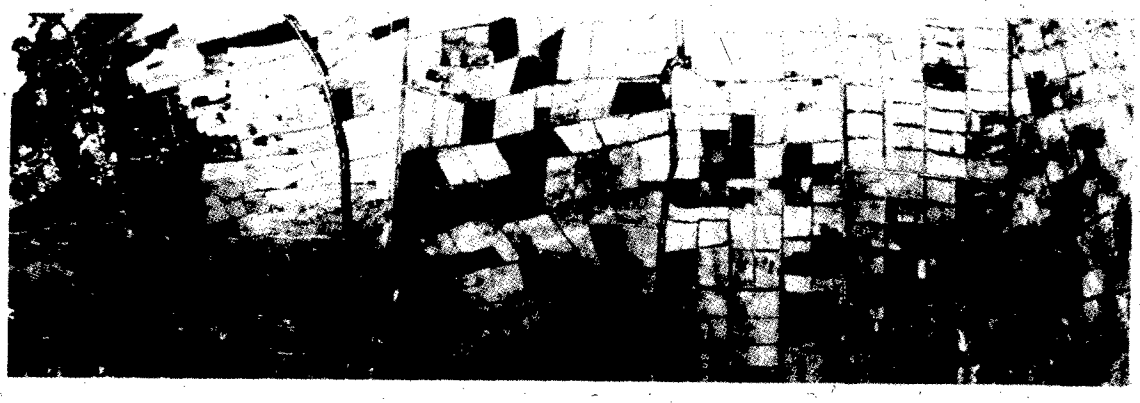
Space Systems for Investigating the Earth's Resources and Monitoring the Environment

A space system must include automatic subsystems for the nonroutine observation of the earth ensuring the collection of photographic multispectral information, automatic subsystems for the routine observation of the earth, ensuring the collection of multispectral videoinformation from optical-electronic and radiometric means with its transmission along spacecraft-earth radio links to the data reception point, a subsystem of surface data reception points, centers for the preliminary processing and dissemination of information. In addition, the space system includes a subsystem of aircraft laboratories ensuring detailed investigation (in case of necessity) of local regions, a subsystem of ground standard polygons ensuring the obtaining of "key" data for the analysis and interpretation of information obtained using aircraft laboratories and space vehicles, and a center for control of the system.



Spectrally separated images of earth's surface below aircraft obtained using optical-electronic television system. [MKM = μm]





At the present time there are no operational systems in any country because the checking out of means and methods is in progress, but to one degree or another all the mentioned subsystems are already functioning.

The subsystem for nonroutine observation of the earth can be an automatic space vehicle which carries a multispectral photographic complex and a surface subsystem for seeking out and evacuation of a vehicle which has landed. This subsystem functions in the following way. After launching of the space vehicle and confirmation of the fact that it has been put into the stipulated orbit, the work program of the on-board photographic complex is activated. After implementation of the program, by a special command from the earth the vehicle is landed in the stipulated region. The search subsystem monitors the entire landing system, determines the precise landing site and ensures evacuation of the vehicle. The materials with the multispectral information are delivered to a special center for preliminary processing. At this center there is photochemical processing of light-sensitive photographic materials, improvement of the illustrative properties of multispectral photoinformation, its geographical tie-in, duplication and transmission to the direct users in the form of color-separated black-and-white negative and positive images of stipulated regions on the earth's surface on a transparent base or photographic paper. In a number of cases it can be transmitted in the form of synthesized color photographs. These materials are accompanied by calibration data ensuring visual-instrumental methods for analysis and interpretation and descriptions of the survey conditions (the altitude from which the survey was made and the time when it was carried out).

The subsystem for routine observation of the earth should include one or more automatic space vehicles of the same type whose orbital planes are displaced relative to one another along the equator. The inclinations of the orbital planes and the flight altitudes for all the space vehicles of this subsystem are identical.

One of the important conditions for the comparability of the multispectral videoinformation obtained at different times for one and the same regions of the earth is their identical illumination by the sun. This condition is ensured in a case when a space vehicle is put into a "solar-synchronous" orbit which ensures the daily passage of the space vehicle over any sector of the earth at one and the same local time. In the considered subsystem the necessary periodicity in scanning of the earth's surface is ensured by the proper selection of flight altitude and the correct number of simultaneously functioning space vehicles. For example, with a flight altitude of one space vehicle of about 1,000 km there is assurance of observation of one and the same regions on the earth's surface with a periodicity of 16-18 days, during the flight of two -- 8-9 days, etc.

In the subsystem for routine observation of the earth multispectral information is transmitted to the earth through radio links. The ground apparatus of these radio links is part of the ground data reception points; in turn these form an independent surface subsystem. Each reception point in this subsystem

includes an antenna complex, receiving apparatus, a complex for the primary processing of the received signals, a complex of different types of communication apparatus, computers, and material-technical and power support facilities.

At the data reception point the signals received from the space vehicle, carrying multispectral information, are decoded and undergo primary processing. The principal content of primary processing is brightness and geometrical correction of videoinformation, its geographical tie-in, addition of service data and registry of the total volume of videoinformation on magnetic carriers. After these operations the multispectral information is transmitted to a special center for preliminary processing and dissemination.

At the mentioned center the multispectral information is transformed in accordance with the requirements of the users, is duplicated and is transmitted to the users in a form registered on magnetic carriers or in the form of images of the surveyed regions of the earth.

The analysis and interpretation of the multispectral information received from space vehicles is accomplished by the users. In the analysis and interpretation use is made of data received when carrying out surface measurements and investigations in standard polygons.

We have examined the most general ideas concerning multispectral methods for investigating the earth's resources by means of space vehicles. It can be asserted that with their development and improvement the effectiveness of the investigations will constantly increase and the benefits received in the national economy will constantly increase.

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SCIENTIFIC-TECHNICAL PROGRESS, QUALITY AND RELIABILITY OF FERROUS METALLURGY PRODUCTS OF THE USSR

Leipzig NEUE HUETTE in German No 5, 1977 pp 233-239

[Article by A. G. Shanimov, Moscow: "Scientific-Technical Progress, Quality and Reliability of Ferrous Metallurgical Products of the USSR"]

[Text] Metallurgy of ferrous metals is one of the most important branches of heavy industry; in many ways, it determines the development of other branches of the national economy. Most ferrous metallurgical products are used in the building industry, in electrical engineering, electronics, aviation, and in the petroleum and gas industries; but they are also used in the production of agricultural machinery, transportation equipment, motors, and consumer goods.

In the most important branches of the machine building industry, the share of ferrous metals (in terms of mass) of the total requirements of construction material amounts to over 96 percent. Consequently, technological progress is inconceivable without continuous increases in the efficiency of ferrous metal production, without reductions in the quantity of metal used for finished products and without extension of their service life. Ferrous metallurgy must concern itself here with further improving quality and with extending the assortment of rolling mill products, pipes and light-section iron on the basis of the introduction of new and progressive technologies, the modernization of obsolete equipment and the automation of production.

During the Ninth Five-Year Plan, the scientific-technological progress of ferrous metallurgy in the USSR is characterized by changes--in regard to quality as well as to shape--in the range of metal products.

During the period from 1971 to 1975, production was begun of 300 new alloys and types of steel. In the new assortment, there were significant improvements in regard to qualitative properties such as strength, resistance to brittle fracture, cold-shortness threshold, weldability and annealability, corrosion resistance in a state of stress, purity

in relation to nonmetallic inclusions, gas content, etc. New developments included effective steel qualities and technologies for the production of sheet iron used in the production of large-diameter gas pipes. High mechanical values were obtained here: tensile strength 550 to 600 N mm^{-2}, notch impact strength at -60°C 4050 J cm^{-2}.

There were improvements--in terms of quality as well as of variety--in the composition of isotropic and anisotropic electrotechnical steels. There was an 11-fold increase in the production and dimensional accuracy of transformer steel with electric insulation plating. Consequently, the mean specific losses of electric energy in products made of this type of steel decreased by 20 percent. Production of the new type of unalloyed dynamo steel, which is characterized by high magnetic induction and low specific losses of electric energy, increased by a factor of 24.

There were significant increases in the production volume and quality range of continuously cast slabs and blanks.

There were rapid increases in the production of heat-treated hot-rolled metal products. From 1971 to 1975, production of heat-treated reinforcing steels increased by a factor of 2.4, production of heat-treated bars by a factor of 1.3 and production of normally annealed heavy plates by 1.7.

At the same time, there were also changes in the range of rolling mill products. New production included 321 hot-rolled sectional steels, 234 cold-bent sections, and 338 sectional steels of great dimensional accuracy. The mean thickness of hot-rolled thin-gauge plates was reduced by 2.7 percent. New production also included some types of cold-rolled strips and sheets of great dimensional accuracy and evenness. With the production of finished rolling mill products increasing by a factor of 1.2, the output of rolled sheet metal increased by a factor of 1.3; production of cold-rolled sheets increased 1.33 times; cold-rolled transformer steel, 1.34 times; bent sections, 2.5 times; rolling mill products made of alloyed steels, 1.3 times; low-alloyed steels, 1.64 times; sectional steels with minimal tolerances of deviation, 4.6 times and cold-drawn calibrated steel, 1.7 times.

New production also included automobile steel plates with minimal gauge deviations and of high surface quality.

For the ferrous metallurgy of the USSR, the Tenth Five-Year Plan is a plan primarily concerned with efficiency and quality. The problem of improving product quality is of crucial importance for continued scientific-technological progress and for increasing production efficiency. The efficient use of metal is the most important precondition for the acceleration of technological progress in the metal working branches of

the national economy. The systematic study of the consumers' demands in regard to the quality of the finished products and the analysis of their proposal show that most of them (ca.70 percent) refer to production and are concerned with the quality of the rolling mill products, pipes and light-section iron.

Regarding the demands raised by the users, there has been a marked increase--aside from the traditional demands for extending the range of goods and for improving metal properties--in the demands for a "pure" steel containing no more than specified amounts of sulfur, phosphorus gases, nonmetallic inclusions and other impurities as well as for high-grade finished rolling mill products with minimal dimensional tolerances and improved surface and heat treatment.

There is no doubt that the users' demands in regard to the quality of the metal products are technically well-grounded.

In fact, during the last few years the development of basic technological fields such as energetics and mechanical conveying was accompanied by the use of machines and equipment, many elements of which must operate under an extremely high degree of alternating and dynamic stress and under the influence of corrosive media as well as high and low temperatures. Construction of such machines requires metal of especially high quality, production of which by traditional processes is frequently impossible. Consequently, the metallurgists must continue to search for new, more effective steel making processes, which will make possible the production of steels of great purity and homogeneity.

During the last 10 years, the metallurgists in the industrialized countries favored the processes of remelting metallic consumable electrodes in chill molds. The steel produced by this method is distinguished by good properties, homogeneity and purity. At the same time, however, it must be noted that this steel is expensive and that in view of the low production volume, it is not possible to meet the great demand for metal of higher quality. Since there will be more and more users requiring metal of higher quality, it is obvious that metal production by means of the remelting process will be extremely complicated and in many cases uneconomical.

The problem of improving the quality of mass-produced steel can be solved more efficiently by the development and utilization of technological processes, which for purposes of eliminating detrimental impurities call for an additional purification of the metal after the tapping of the melting aggregate.

The processes of supplementary metal refinement--which are either in

use or in the process of development--can be divided into two groups: The first group is in the category of mass production characterized by large output in terms of tonnage; it includes processes such as the vacuum treatment of the metal in the casting ladle with liquid synthetic slag, reduction slag, gases, powdery reagents, etc. The second refining process group belongs to the category of relatively low production volumes. The process involves repeated remelting of the prepared electrodes; the drops trickling down from the melting electrode are given special slag or high vacuum treatment. Due to the generally noted trends in steel production, i.e. the increases in the capacity and specific output of the melting aggregates, it is necessary under conditions of mass production to make greater use of processes of steel refinement outside the furnace.

It is well known that through the construction of large melting aggregates, such as electric-arc furnaces and Bessemer converters, it is possible considerably to reduce the specific capital expenditures and production costs and at the same time to increase labor productivity and to improve the working conditions of the operating personnel. As regards the putting into operation of new modern steel mills, which are equipped with complex mechanization systems, installations for environmental protection as well as automated control systems including computers, it is of crucial importance to increase the degree of utilization of the melting aggregates. This can be achieved through specialization in regard to the execution of technological operations, i.e. through oxidizing refinement in acid converters and by the melting--with concomitant partial oxidation--of admixtures in electric-arc furnaces.

The above remarks substantiate the necessity of refining measures: thorough decarbonization, desulfurization, deoxidation and partial alloying outside the aggregates, i.e. in the casting ladles or in special installations. Given the correct set-up, performing these operations outside the furnace offers a number of advantages--in terms of the rate and completeness of the reaction--vis-a-vis the refining of the metal in the furnace, since it is very difficult to carry out these processes in high-capacity melting aggregates; to do so would require extending the duration of heat and would entail a lowering of the technical-economic indexes.

The necessity of developing and broadly applying the technology of refining outside the furnace also entails progressive changes resulting from the continuous casting of the steel, which entails higher requirements concerning the quality of the metal in terms of the content of sulfur, gases, nonmetallic inclusions and in terms of minimal

melting technology for bearing and structural steels and gradually to change over to the electric-arc furnaces of the "Krasnyy Oktyabr" plant. In this case, removal of sulfur, oxygen and nonmetallic inclusions is achieved through treating the steel at the tap hole with a reduction slag of specified composition, which forms in the bath in the furnace.

The long service life of bearings made of metal produced in 200-ton-furnaces was shown to exceed the mean statistical service life by a factor of 2 to 2.5. The annual production volume of this metal amounts to 0.8 million tons; by 1980, it is expected to increase to approximately 2.0 million tons.

The refining effect produced by the reduction slag increases considerably upon injection of the metal with argon (nitrogen). Treatment of the bath with inert gases increases the reciprocal effect of the metal-slag phases, reduces the sulfur and oxygen contents, increases the even temperature distribution and the chemical homogeneity of the steel and improves castability.

The technology of refining steel outside the furnace by flushing the bath in the casting ladle is used more and more widely. In 1980, the volume of argon-treated steel produced in the USSR will amount to 17.0 million tons.

In the last few years further significant advances were made in regard to vacuum treatment of the metal. In its crucible installations, the Cherepovetsk steel mill introduced the vacuum treatment of rimmed electric steel. This technology assures a carbon content of 0.005 percent.

The elimination of the "black" decarbonization annealing of sheet metal and the improvement of metal quality resulted in savings of R20 per ton of production. At the vacuum unit of the "Krasnyy Oktyabr" plant, efforts are presently being made to improve the decarbonization process for non-corroding steel. It is expected that the savings will amount to R40 to 50 per ton of production.

During the Tenth Five-Year Plan, the enterprises under the jurisdiction of the Ministry for Ferrous Metallurgy of the USSR planned to install approximately eight portion and circulation vacuum units; through this expansion, it will be possible to refine a significantly greater volume of steel. Small-scale technical testing demonstrated the possibilities of successfully utilizing certain processes of refinement outside the furnace: For purposes of thorough decarbonization, a vapor-gas-oxygen mixture is injected into non-corroding steel in a special converter-like

variations of temperature and chemical composition.

We would like to make a few comments on the special features of current or newly developed methods of steel and alloy refinement in steel production: During the last few years, there were further scientific advances in the field of steel refinement outside the furnace. At present, steel mills in some countries favor the following processes: Refinement of the steel in the casting ladles by means of liquid reduction slags of specified composition, flushing of the bath with inert gases or nitrogen, and vacuum treatment of the metal in crucible, portion or circulation installations.

Some new processes of steel refinement outside the furnace are at the point of being introduced into the production process: Thorough vacuum-decarbonization of non-corroding highly chromiferous steels, injection of a gas-vapor-oxygen mixture in converter-like units, attainment of a high degree of desulfurization, and killing of the metal by means of injection of powdery reagents (carbide, calcium, calcium silicide, barium, magnesium, rare earth metals, etc.), which are introduced into the bath through submerged blow molding.

It should be noted here that ZN II-Ferrous Metallurgy developed a process of refining steel in the crucible by means of synthetic lime silica slag; regardless of the type of melting unit employed, it is possible through this process to obtain a metal low in detrimental impurities such as sulfur, oxygen, and nonmetallic inclusions; at the same time, this process improves--especially at temperatures below zero--the plastic properties of the steel, giving it a perpendicular fibrous structure.

The quantity of the various steels treated with synthetic slags amounts to approximately 1.5 million tons. When the process of treating 17G2AF tubular steel with synthetic slag was introduced in 1976, it became possible to obtain good mechanical properties in sheets used in the production of large-diameter gas pipes. On account of the putting into operation of four OKB-1320 slag furnaces (NLMZ [New Lipetsk Metallurgical Plant], OKhMK [Orsko Khalilovskiy Metallurgical Plant], "Azov-steel") during the Tenth Five-Year Plan, the output of refined metal will amount to 4.5 million tons in 1980.

More and more widely employed is the improved process of producing high-grade structural steels; the stages of this process are as follows: semi-finished steel product--liquid ferroalloys (key alloys)--synthetic slag--flushing with argon (nitrogen).

Application of the principles of steel refinement by means of synthetic slags outside the furnace made it possible to develop a reliable

aggregate; in the casting ladle, the metal is treated with pulverulent reagents, which are introduced into the bath through gases. On the basis of the test results, the planning organizations were given the most important indexes concerning production of non-corroding steel by gas-oxygen refining; these indexes will be used for designing a specialized electric steel melting plant equipped with 100-ton-electric-arc furnaces.

The positive experience gained in regard to the use of calcium carbide in the desulfurization of steel led to the construction of the installations in the KKZ (Kamyshin Crane Plant) No. 2 NLMZ and in the electric steel plants of the "Krasnyi Oktyabr" steel mill. At present, the equipment is being tested and experimental melt-downs are being carried out. We hope that this procedure will be taken up and that it will occupy its proper place in ferrous metallurgy. The implementation of the above work schedule for the development of the processes of steel refinement outside the furnace makes it possible to meet the industrial demand for high-grade steel to be used in mass production, and it will serve to extend the service life of machines, aggregates and products.

The employment of the electroslag-, vacuum-, electric-arc- and electric steel-remelting processes and the use of the vacuum-induction and plasma melting processes led to fundamental quality improvements in a number of steels and alloys, which are used in products exposed to extreme stress.

The high degree of compositional and structural homogeneity of the metal produced by the refining remelt processes, the total absence of gross impurities and the purity in regard to undesirable admixtures assure a high degree of reliability and durability of the finished products. This also substantiates the practicality and necessity of using metal of great purity in aeronautical and rocket engineering, radio engineering, nuclear energy and other fields, which require utterly reliable instruments, products and equipment.

The electroslag remelting process and especially the vacuum melting processes made possible the development and production of new steels and alloys characterized by better service characteristics; thus it was possible to make significant advances in the above-mentioned fields of technology. For example, the newly developed heat-resistant alloys, which can only be produced in vacuum units, more than tripled the performance of aircraft engines. These advances not only improved the economic indexes for aviation, but they also considerably reduced the demand for engines and consequently the demand for deficit materials such as nickel, cobalt, chromium, etc.

Due to the high degree of uniformity of the mechanical properties (with and across the grain), which is characteristic of 40 KhNMA steel produced by the electroslag remelt process, it is possible to increase the service life of helicopter pipes of varying diameters by a factor of 1.5.

The savings achieved per ton of steel produced amounts to R6,000; of this amount, over R1,200 must be attributed to greater metal economy in the production process, for the products made of metal produced by the ESU (electroslag remelt process) are less expensive.

Likewise very effective was the use of metal produced by the refining remelt process for the production of roller bearings. In the case of ESU-steel, the average service life of railroad bearings increased from 620-790 hours to 1,030-1,240 hours. One could adduce analogous examples from other technological fields: There are significant increases in the edge life of drill bits made of steel produced by the refining remelt process. Marked improvements were noted in regard to the magnetic properties of magnetically soft materials.

The technology of the refining remelt processes and the design of the aggregates are being improved on a continuing basis. Two new electroslag furnace models have been developed in the USSR: the ESP-10 and the ESP-20. These models represent a new furnace generation. In their design, use was made of the experience gained in the operation of previous furnace models. The furnaces make possible the production of large square ingots measuring 650 x 650 mm across and of flat sheets measuring 500 x 1,000 mm across. In the development stage is a new generation of vacuum arc furnaces for the production of ingots up to 10 tons with round, square and oblong chill molds.

Thanks to the last-mentioned types of chill molds, it is possible to solve the problem involved in rolling VDP (vacuum arc melting) ingots on present rolling trains without pressing or forging. The new electroslag and vacuum arc furnaces are equipped with a modern automatic control system. In the development stage is an automatic control system equipped with mini-computers.

The projected automation and the design changes in the new furnaces have one objective: maximum stabilization and standardization of the process; total elimination of any deviations from the technological process, not only within the individual charge, but within the entire series.

In order to ensure standard metal characteristics, it is necessary to pay attention to the preparation of the raw metal for the subsequent

refining remelt process. The metals used in the production of heat-resistant alloys have to meet especially strict requirements in regard to the content of nonferrous metal admixtures (lead and bismuth in nickel approximately 0.0005 percent). In connection with the start of production of new, more highly alloyed, heat-resistant alloys, it is necessary further to raise the requirements and to introduce restrictions in regard to the content of tellurium, thallium, silver, selenium, etc. These strict requirements also apply to mild steel, which is used in the vacuum melting of non-corroding special steels, precision alloys and other products.

Top-quality steels and alloys are as a rule produced by a combination process: a vacuum induction process followed by a vacuum arc or electron-ray remelt process.

In most cases, however, the raw metal is produced in open melting units: electric-arc and SM furnaces, acid converters as well as plasma furnaces.

As regards the production of structural steels by means of the electro-slag remelt process, melting of the raw metal in acid converters proved to be an efficient technology. As compared to the electric furnace process followed by electroslag remelting, the nitride inclusions were reduced here by a factor of 10 to 15; at the same time, there was a drop in steel production costs.

A serious problem in the field of electroslag remelting is the development of measures aimed at reducing the hydrogen content. So far, no cardinal solution has been found. During the electroslag remelting, the hydrogen concentration in the metal shows a slight increase. The basic methods of obtaining an acceptable hydrogen concentration in steel produced by electroslag remelting are the reduction of the hydrogen content in the raw metal (vacuum treatment of the liquid metal, and other procedures) and the protection of the melting zone from air and other potential sources of humidity.

Another problem in regard to refining remelt processes is the further improvement of the structural quality of the ingots, the attainment of an arborescent, chemically inhomogeneous and finely dispersed dendrite structure. Work is in progress on some technologies, which could increase the remelt rate without impairing the micro-structure or the dendritic chemical inhomogeneity (use of the magnetic field in electroslag remelting, use of oblong chill molds in electroslag remelting and vacuum electric-arc melting, control of the ingot cooling process in the vacuum arc remelting process, and other technologies).

A very serious problem is the reduction of production costs in the refining remelt process. The main approaches toward solution of this problem are the following: employment of consumable electrodes produced by continuous casting or by casting into special ingot molds, increasing the ingot mass, increasing the productivity of the aggregates, improving the ingot surfaces, etc.

Improvements in the monoblock and continuous casting of semi-finished products represent one of the reserves for improving quality in metal production. Through the wider use of slag and exothermic mixtures, it was possible considerably to improve the surfaces of the rolled products, to reduce production losses and to increase the output of high-quality products. The introduction of continuous casting installations equipped with chill molds of an improved design, protection of the jet from repeated oxidation, the use of new compositions of exothermic mixtures and of protective charges as well as the employment of prescribed casting procedures and other measures assure continued improvement of the quality of slabs and semi-finished steel products. On the long view, through combining the technology of steel refinement outside the furnace with the continuous casting process, it will be possible to attain higher quality indexes as well as greater stability of metal properties.

It is well known that the physical-mechanical properties of the finished rolling mill product are determined not only by the chemical composition and purity of the steel, but also by the melting and casting conditions and by a whole complex of technological factors, which act on the metal during hot and cold rolling, during the heat treatment and planishing, and also during the application of surface coating.

In accordance with the intended use of the metal products, optimal procedures in regard to temperature control and deformation during the rolling process and in regard to the heat supply during heat treatment are being developed for certain grades of steel so as to assure the required characteristics.

The ferro-metallurgical enterprises of the USSR have started to develop controllable rolling processes, which will enable them to obtain low-alloyed steel exhibiting--in the hot-rolled state--a special complex of mechanical characteristics. This progressive process of thermoplastic treatment makes possible the employment of new slightly pearlitic,weldable steels. These steels are characterized by increased resistance to brittle fracture and by high economy values. On account of these properties, they can be used in the production of metal goods designed for high-duty service, above all in reproduction of large-diameter gas pipes.

The establishment of specialized set-ups for the production of electro-technical steel led to the introduction of new technological production programs. Through the use of rigid cluster roll stands for the cold rolling of transformer steel, it was possible significantly to increase the dimensional accuracy of the steel plates.

Another method of improving the mechanical characteristics of the steel is the employment of heat treatment for hot- and cold-rolled metal. A considerable increase in the share of heat-treated metal was made possible by the use of new heat treatment installations, especially of aggregates for the standard annealing of hot-rolled plates.

The surface finish of rolled products is one of the most important quality criteria in ferrous metallurgical products. Measures aimed at improving the surface of ingots used in steel melting plants do not rule out the necessity of clearing away surface defects on semi-finished and finished rolled products by means of dressing (desintering). Elimination of defects in prior operational sequences serves to reduce the energy expended in dressing and to attain an improvement in the surface quality of the rolled steel. The increased use of machines for the sinter dressing of surfaces in technological production processes, careful inspection and the use of highly mechanized equipment for the dressing on adjusting installations made it possible to improve the surface quality (especially the surfaces of automobile body sheet steels) and to start production of new types of rolled plates calling for special surface treatment. Use is made of progressive dressing methods such as pin milling, shot blasting and other processes.

By means of lubricating coolants with optimal physical-chemical properties, it is possible considerably to improve the rolling conditions, surface finish, evenness and dimensional accuracy of hot- and cold-rolled sheets. Various industrial lubricants developed for cluster reversing rolling mills and draw benches have been introduced into the production process.

One of the most important quality indexes in regard to metal products is the dimensional accuracy. At present, continuous broad strip rolling trains for hot rolling and continuous cold rolling trains are equipped with automatic gauge regulation systems. Such highly advanced systems are used in cluster rolling mills; thus it is possible to roll strips with gauge variances of only a few micrometers.

The production of plated rolled products was thoroughly modernized. The new aggregates for hot tin plating show a number of improvements,

which make it possible considerably to increase the output of the aggregates, to improve the quality of the plating and to produce various types of tin-plated goods requiring just the minimum quantity of tin needed for the intended use of the product. A test aggregate for a new production process for the polyvinyl chloride (PVC) coating of strips was put into operation.

As a result of the measures aimed at improving the quality and extending the range of rolled goods, total metal savings in the USSR, which are related to the extraordinary increases, are expected to amount to approximately 1.0 million tons in 1976.

Proceeding from the general technological development trends during the Tenth Five-Year Plan, it is planned to step up the present efforts to improve the surface quality and dimensional accuracy of the rolling mill products. It is planned to establish continuous algorithms for the control of broad strip rolling trains and to develop new technologies for the production of complex bent rolled steel sections, of strip steel of improved dimensional accuracy, of strips made of precision alloys and of thin transformer strips. Work has begun on the continuous cold rolling process. Plans provide for a qualitatively new level of rolling process automation.

The development of the controllable rolling process will provide the basis for expanding the production of metal of great plasticity and strength, which will also be used for products intended for the high north.

It is planned considerably to increase the production volume and to raise the technological level in regard to the production of heat-treated metal. In the development stage is a process of heat treatment in pusher-type furnaces, in which the air can be regulated and re-carburized.

Aside from the customary assortment problems such as rolling accuracy, tolerance zone, surface quality and surface decarbonization, two particularities concerning the hot forming processes call for special consideration: If the metal is used in the construction or the machine without additional heat treatment, a fine-grained structure is absolutely essential for a steel of satisfactory quality. For this reason, it is recommended to keep the final temperature in the hot forming process as low as possible. This condition must be met even if it affects mill output.

If a rolling mill product is to be produced from deformation-resistant complex steels and alloys, it is practical to employ the hot-extrusion molding or extrusion process. Theoretical experiments and tests have shown that through this process it is possible to attain a high degree of deformation even in deformation-resistant steels. Figuratively speaking--this process makes it possible to shift the alloying barrier to higher concentrations, with the height of this barrier being determined by the possibilities of hot forming.

Aside from the development of progressive processes of metal shaping, a great deal of attention is directed to the further extension of the range of rolling mill products. The sharp increase in the production of cold-rolled plates represents a crucial step in expanding the assortment of rolled products; we are referring here to the construction and putting into operation of a large-scale specialized plant for the production of cold-rolled plates made of non-corroding steels. The production of cold-rolled electrotechnical steel will show a threefold increase, while the output of cold-drawn section steel and cold-rolled strip steel will double. The production of precision alloys to be used in apparatus construction will be considerably expanded.

On the basis of the completion of complex research work, it is planned to start production of very thin plates (up to 0.08 mm), chrome-plated sheets, of zinc-plated sheets, sheets with polymer and aluminum platings, and of strip steel with nickel, chromium and other platings applied by means of thermodiffusion. It is also planned to develop aggregates for high-productivity hot zinc plating (up to 500,000 t a^{-1}). Work is being continued on the development of processes for the production of new types of sheet metal platings from aluminum, titanium and other metals by means of the electron ray vacuum method and from powders of these metals in the electrostatic field; other studies are concerned with the development of new processes for the application of polymer coatings including coatings made of pulverulent dyestuffs for lake-making.

Of great importance in the metallurgy of quality steels is the heat treatment. While the user will subject the product to a complete heat treatment, the heat treatment in the metallurgical plants is concerned merely with the soft annealing of the steel to ensure mechanical workability. If the metal is to be used without additional heat treatment, the heat treatment in the metallurgical plants is indispensable.

In our metallurgical plants, complete heat treatment (hardening and tempering) is often carried out even under conditions of mass production (rails, reenforcement steel, sheets for gas and oil pipes, etc.). Heat treatment installations are now an integral part of the rolling mills.

In the next few years, the metallurgical plants plan to introduce a number of new shops and installations for the heat treatment of the rolled products. Of special interest in this respect is the thermomechanical process. By combining low temperature shaping with subsequent heat treatment, it is possible to obtain high ultimate stress stress values ($\geq$ 2,500 to 3,000 N mm^{-2}), while retaining a sufficient plasticity reserve.

At present, some plants are setting up specialized shops equipped with the installations necessary for the production of high-strength metal by means of the thermomechanical process. An industrial test set-up of this type was established in the "Krasnyi Oktiabr" mill; in this plant, it is also planned to set up an installation for the production of high-strength metal.

The thermomechanical process has great developmental possibilities and it is widely used in the production of high-strength alloyed steel.

In many respects, successful development of high quality metallurgy was furthered by the creative collaboration of scientists and specialists in the plants, who carried out joint research work on problems of immediate interest. The most important developmental projects in the field of science and technology of high-quality metallurgy, which are to ensure further progress in this industrial sector, include

--improvement of present methods and development of new, more effective methods of steel refinement outside the furnace, and on this level, the development of reliable technological equipment;

--development and introduction into the production process of an automatic control system for the melting process, the treatment of the metal outside the furnace, and the casting of the steel;

--control of the extrusion process, applied to a wide range of alloyed steel products, including bearing steel;

--improvement of the rolling mill production processes and installations;

--development of more efficient methods of heat and thermomechanical treatment as well as a number of other processes.

Widely used in some branches are high temperatures and pressures, high speeds, aggressive media, extremely low temperatures, etc. In connection with such procedures, it is necessary to develop means of raising the steel and alloy property indexes and to develop new materials with a special combination of special characteristics. In order to solve these problems, it appears practical to carry out theoretical and research

work along the following lines:

--Search for methods of significantly increasing the strength of steels and alloys (treatment for hyperfine grain, tempering under stress, utilization of the explosion energy, controllable austenite decomposition, deforming of the austenite and martensite by means of liquids or gases under high pressure conditions, etc.). In some cases, it has been possible to attain an ultimate stress value of approximately 3,500 N mm^{-2};

--development of fundamentally new types of steels and alloys, including the development of compounds and methods of producing solid solutions characterized by increased heat-resistance and other positive properties;

--development of physical methods of influencing the production and treatment processes for steels and alloys, including the treatment with nuclear energy;

--investigation of the phase reversals, of the nature of strength and plasticity and of the crystallization patterns of steels and alloys;

--development of methods of controlling the composition, form, distribution and quantity of the nonmetallic inclusions in the steel;

--use of ultrasound in the production and treatment of steels and alloys, especially in the refinement of the microstructure and in the reduction of liquation homogeneity during the crystallization process;

--investigation of the potential uses for the new developments in magnethydrodynamics in the fields of steel transportation, casting and refinement;

--investigations in the field of the utilization of heat from nuclear reactors for the production and heating of reducing gases for direct reduction processes.

In regard to solving the problems involved in improving the quality of the metal and in increasing the efficiency of its utilization in the metalworking industry, standardization is of great importance; it is one of the organizational-technical foundations of systematic quality control, and it is an effective means of raising the technical-economic production indexes.

In the USSR, almost the entire output of this industrial sector (approximately 98 percent) is presently produced in accordance with approximately 1,500 state standards and 5,500 technical delivery specifications. In this industrial branch, there are 18 basic organizations for the standardization of certain modes of production; in regard to scientific-methodological guidance and the coordination of work, these organizations are controlled by ZNII Ferrous Metallurgy, which has a department concerned with standardization in the field of ferrous metallurgy.

With regard to the period from 1976 to 1980, plans provide for the revision of approximately 460 current standards approved until 1972 and for the review of the technical delivery specifications approved before 1975.

During the period from 1976 to 1980, the development of standardization will proceed along the following lines:

--Raising the technical requirements in regard to product quality, widening the range of products, standardization of steel brands;

--standardization of new methods of examining the properties of ferrous metals and ferrous metal products;

--development of reference samples, model measuring apparatus, and standard samples of materials;

--speeding up the development and introduction of new standards;

--improvement of measuring procedures.

One of the new research trends during the Tenth Five-Year Plan is the organization of systems of production quality control for the entire industrial sector. Such systems include the testing of metal quality and the development of guidelines as technical and operational standards, which as elements of the control system will affect product quality in all stages--from the research stage to the industrial production stage.

In summary, it is necessary to emphasize the importance of the tasks confronting ferrous metallurgy, which involve ensuring a high degree of efficiency in the course of scientific-technological progress. The constant improvement of production through the introduction of new technologies and the stabilization of the technological parameters and processes make it possible significantly to improve the quality of the metal products, i.e. rolling mill products, pipes and light-section iron.

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PHYSICS AND MATHEMATICS

BAKSANSKAYA NEUTRINO OBSERVATORY IN OPERATION

Moscow PRAVDA in Russian 10 Nov 77 p 3

[Article by A. Logunov, Vice-President of the USSR Academy of Sciences: "The Neutrino Tells Its Story"]

[Text] On the eve of the 60th anniversary of the October Revolution the arsenal of equipment at the disposal of Soviet science has been enlarged with the addition of a unqiue physics complex--the first stage has been completed in the construction of the Baksanskaya neutrino observatory of the Institute of Nuclear Research of the USSR Academy of Sciences, and regular scientific operations have been started with the world's largest underground neutrino telescope and in the low-background laboratory of the observatory. The devices put into service are opening new paths in the discovery of the fundamental laws governing the evolution of the universe.

At present, science recognizes four types of forces: gravitational, electromagnetic, nuclear and weak forces. There is universal recognition of the importance of the role played by the discovery of the nature of the first three types of forces and the tremendous practical uses that have come from their study.

In the last two or three decades using elementary particle accelerators in this country and abroad, scientists have gained a deeper understanding of a new, fourth type of force which has been named the "weak" interaction. The material carrier of "weak" forces is a particle--the neutrino. The word "weak" is put in quotation marks with good reason. The interaction forces of neutrinos with other particles are small only at great distances, but grow rather quickly as the energy of the neutrino is increased. It is highly probable that at very small interparticle distances these forces are comparable to or even greater than electromagnetic forces. Observing the interaction processes of high-energy neutrinos with other "elementary" particles presents a possibility for studying their structure such as no other reactions can provide. The fundamental role of weak interactions in the structure of elementary particles and in nature in general is evidently only just beginning to be discovered.

On the other hand, because it interacts with particles only when it closes to very short range, the neutrino possesses a truly enormous penetrating ability. All bodies, no matter how massive, are for all practical purposes transparent to the neutrino. This is why there is such great interest in the prospects for neutrino astronomy.

Recent decades have marked the birth and rapid development of new approaches and methods in the study of the universe--radio astronomy and x-ray and gamma ray astronomy. This has brought a large number of discoveries of the greatest importance: scientists have learned of completely new types of astronomical objects--quasars and pulsars, and the residual radiation from the formation of the universe has been detected. Finally, the study of cosmic rays--fluxes of protons, nuclei and electrons--has enriched our knowledge of the processes under way in outer space. All this has added remarkably to our understanding of the complex structure of the developing universe.

At the same time, none of the methods mentioned has allowed a glimpse of the interiors of astronomical objects nor the gathering of any direct information on the processes under way there. In fact, massive astronomical objects are opaque to electromagnetic radiation and cosmic rays, and with their aid we can observe only the processes taking place near the surfaces of such bodies. It is clear that direct methods of observing processes in stellar interiors can provide information on the mechanism of energy generation there. Neutrino astronomy is just such a fundamentally new method for the study of nature.

According to current views, thermonuclear fusion reactions within stars are the source of their internal energy. One of the products of these reactions is the neutrino. As the density and especially the temperature of stellar matter decrease, the rate of these reactions drops so quickly that they proceed only in a small central region of the star.

Science does not yet have any direct experimental data showing that this is in fact the nature of energy production in the sun, or whether that natural thermonuclear reactor, the sun, operates at constant power, or even whether the intensity of the reactions in its core changes with time without being reflected in such observable solar characteristics as its size and brightness. Neutrinos, being direct participants in the processes within stars, escape unhindered, carrying with them information in undistorted form on conditions in the place where they originated. If experiments failed to reveal the flow of low-energy solar neutrinos arising from the basic thermonuclear energy production cycle, this could mark the overthrow of all current concepts of energy production in stars. Experiments of this sort have not yet been conducted because suitable detectors did not exist. Data now available on solar neutrinos of higher energies have shown that the contribution of various thermonuclear reactions to the spectrum of neutrinos emitted by the sun is somewhat different from that expected. The study of these problems is one of the most important tasks of science today. Observations of the neutrino activity of the sun will aid in taking an important step forward in our understanding of the nature and evolutionary paths of stars.

When stellar sources of nuclear energy are exhausted, the star enters a stage of gravitational compression which culminates either in the formation of a white dwarf or the birth of a pulsar in a supernova explosion, or perhaps in a gravitational "collapse" into the "black hole" state. In all these processes, neutrinos are also formed and released. Experimental confirmation of these theoretical predictions is of fundamental interest.

Finally, in accordance with the expanding universe hypothesis, it is expected that there are neutrinos of extremely high energy remaining from the universe's bright stage when the processes of the formation and explosion of stars and galaxies were proceeding with great intensity. The discovery and study of these neutrinos is an experimental task of exceptional importance.

It was with a view to the urgent problems of neutrino astrophysics that a decision was made for the creation within the USSR Academy of Sciences of a specialized complex for conducting the appropriate research.

On the threshold of the 60th anniversary of the October Revolution the USSR Academy of Sciences and the Kabardino-Balkarskiy obkom of the CPSU reported to the Central Committee of the CPSU and to the General Secretary of the Central Committee CPSU and President of the Presidium of the USSR Supreme Soviet, Comrade L. I. Brezhnev, that socialist obligations had been successfully fulfilled and that the underground laboratory, which is without equal in the world, and the unique scintillation telescope of the Baksanskaya observatory had been put into regular scientific use ahead of schedule.

In the process of creating the observatory, the members of the Institute of Nuclear Research had to solve a number of complex scientific, design, and production problems. The physical start-up of the underground scintillation telescope and the low-background laboratory has now been accomplished, and initial work on the planned program has begun.

The neutrino scintillation telescope of the Baksanskaya observatory is installed in an underground chamber 550 meters from the mouth of an adit leading deep into Mount Andyrchi. The chamber is a remarkable underground laboratory space of 15,000 cubic meters' volume with a reduced background of natural radioactivity and cosmic rays, creating exceptionally favorable opportunities to conduct the most exacting physical experiments. Lowering the background of penetrating cosmic radiation by thousands of times was achieved by locating the chamber deep under the earth, and the background of natural radioactivity was reduced through the use of specially developed concrete of low radioactivity.

The scintillation telescope, a huge nuclear physics device both in its dimensions and in the volume of information it can record, is a four-story structure containing several thousand detector modules. Information from each of these is simultaneously and independently recorded by electronic devices and then analyzed by a data processing center using computers. The telescope

is supplied entirely with Soviet equipment. This is a multi-purpose physics instrument for conducting a set of fundamental investigations in the field of astrophysics and particle physics. It is capable of recording neutrinos arising from the gravitational collapse of stars at any point in our galaxy.

Broad possibilities are being opened for research in the physics of cosmic rays.

The basis for current concepts of the nature of weak, electromagnetic, and strong interactions is the law of the conservation of baryon and lepton charge, which is reflected, in particular, in the stability of neutrinos and protons--the basic form in which matter exists in the universe. The telescope makes it possible to advance further in verifying this fundamental hypothesis than has been the case until now.

The first stage of the Baksanskaya observatory has established the basis for the expansion of work on the seond stage of the observatory, the principal goal of which will be the creation of extremely sensitive radiochemical detectors in order to record neutrinos from the sun. When these are put into operation, it will be possible to carry out a program neutrino spectroscopy of our sun.

Now, in addition to large-scale development of the recognized method based on the conversion of chlorine into argon by neutrinos, laboratory tests are proceeding on a new and promising method in which solar neutrinos convert gallium nuclei into germanium nuclei. This will make it possible for us to finally verify our ideas of the mechanism of generation of the sun's energy.

The creation of the Baksanskaya neutrino observatory is a tremendous achievement of Soviet science. The further development of the observatory will enable Soviet scientists to implement the long-term program developed in the USSR Academy of Sciences for research in neutrino astrophysics.

9187
CSO: 1870

UKRAINIAN ACADEMY OF SCIENCES ANNOUNCES MEMBERSHIP OPENINGS

Kiev PRAVDA UKRAINY in Russian 18 Nov 77 p 3

[Notice from the Presidium of the Academy of Sciences Ukrainian SSR]

[Text] In conformity with articles 19 and 20 of its by-laws, the Academy of Sciences Ukrainian SSR hereby gives notice of existing vacancies as full members (academicians) and corresponding members of the Academy of Sciences Ukrainian SSR in the following specializations:

	Academician	Corresponding Member
Division of Mathe-, matics, Mechanics, and Cybernetics		
Mathematics	-	2
Mechanics	1	3
Mathematical Theory of Reliability	1	-
Computer Mathematics	-	1
Systems Engineering, Systems Theory	1	-
Division of Physics		
Physics	-	1
Theoretical Physics	-	1
Solid State Physics	1	1
Physical Electronics	-	1
Experimental Nuclear Physics	1	-
Division of Earth Sciences		
Physics of the Sea	1	-
Geology	-	1

	Academician	Corresponding Member
Division of Physico-Technical Problems, Study of Materials		
Study of Materials, Strength of Materials	1	1
Metallurgy, Technology of Metals	-	1
Study of Semiconductor Materials	-	1
Division of Physico-Technical Problems of Power		
Thermal Power	-	1
Electrical Engineering	-	1
Division of Chemistry and Chemical Technology		
Inorganic Chemistry	-	1
Electrochemistry	1	-
Organic Chemistry	-	2
Chemical Technology	-	1
Physical Chemistry and Technology of Inorganic Materials	-	1
Division of Biochemistry, Physiology, and Theoretical Medicine		
Physiology, Medicine	1	1
Cryobiology	-	1
Zoology	-	1
Hydrobiology	-	1
Division of Economics		
Economics	-	1
Division of History, Philosophy, and Law		
USSR History	1	-
History	-	1
Philosophy	1	-

	Academician	Corresponding Member
Division of Literature, Language, and Study of the Arts		
Literary Studies	1	1

According to Article 14 of the By-Laws of the Academy of Sciences Ukrainian SSR full members (academicians) must be scientists who have enriched science with works of primary scientific significance.

Corresponding members of the Academy of Sciences Ukrainian SSR, according to Article 15 of the By-Laws of the Academy of Sciences Ukrainian SSR, must be scientists who have enriched science with outstanding scientific works.

The councils of scientific establishments and higher educational institutions, state and public organizations, and full and corresponding members of academies of sciences have the right, within one month of the day of publication, to send the Academy of Sciences Ukrainian SSR letters, with appropriate supporting material, nominating candidates for full membership (academicians) and corresponding membership in the Academy of Sciences Ukrainian SSR in the specializations listed in this notice (Article 21 of the By-Laws).

The following documents must be appended when nominating candidates for full and corresponding membership of the Academy of Sciences Ukrainian SSR (in two copies): The report (decision) of the council or state or public organization or a letter with appropriate supporting materials nominating the candidate, an autobiography, an individual personnel sheet with a 4.5 × 6 centimeter photograph, a description of the candidate's production and social activity, copies of diplomas granting academic degrees and titles, a list of scientific works (form No 3) and comments on their significance for communist building in the USSR.

A candidate cannot be registered if any of the documents listed above is not submitted.

All materials should be sent to the following address: 252601, Kiev-30, GSP, Vladimirskaya, 54, Academy of Sciences, Ukrainian SSR.

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